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Fish Ecology Division

Northwest Fisheries Science Center

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Seattle, Washington

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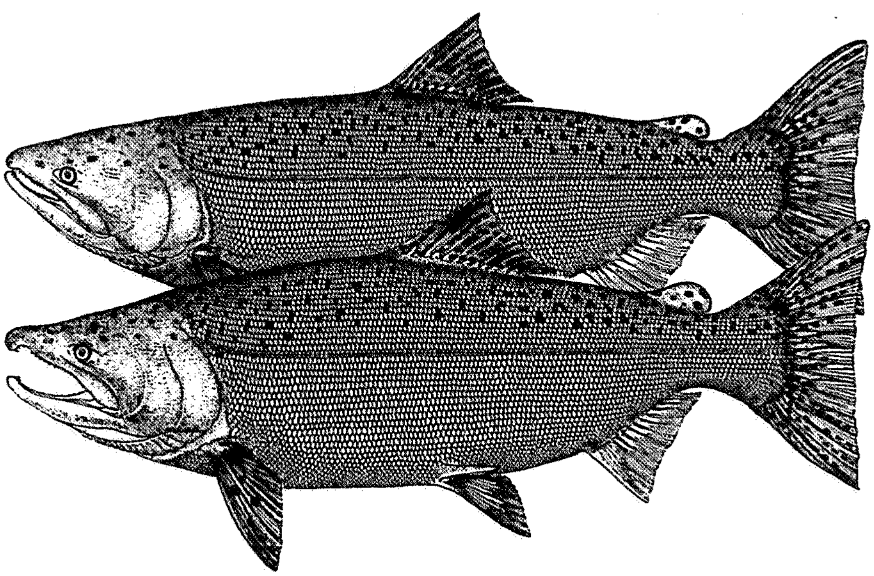
May 2003



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Report of research by

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EXECUTIVE SUMMARY

In 1999, National Marine Fisheries Service (NMFS) researchers continued evaluation of a surface trawl containing a passive integrated transponder tag (PIT tag) detector for estuarine detection of PIT-tagged juvenile Pacific salmon *Oncorhynchus* spp. The evaluations, which began in 1995, were conducted in the Columbia River estuary at Jones Beach, River Kilometer (RKm) 75.

Fish targeted for detection were the nearly 125,000 juvenile spring/summer chinook salmon *O. tshawytscha* and 115,000 juvenile steelhead *O. mykiss* PIT-tagged for NMFS transportation studies and released at Lower Granite Dam on the Snake River or transported and released in the Columbia River 9 km downstream from Bonneville Dam. In addition to these targeted fish, we detected migrating coho and sockeye salmon PIT tagged for other studies throughout the basin. Objectives for sampling with the PIT-tag detector/surface trawl during 1999 were as follows:

1) Provide and compare information on migration behavior and timing for fish groups tagged and released at Lower Granite Dam and groups transported and released downstream from Bonneville Dam.
2) Provide estuarine passage dates that allow survival comparisons between adult fish groups that entered the ocean as juveniles at similar times.
3) Document the diel behavior of juvenile salmonids in the estuary.
4) Provide accurate counts, by origin (wild or hatchery), migration history, and species for smolts entering the estuary for estimates of the relative vulnerability of these groups to predation by seabirds nesting in the middle and lower estuary.
5) Provide survival estimates to Bonneville Dam for various release groups of juvenile salmonids migrating in river.

In 1999, we developed a new detection system using improved electronics that allowed a fish passage tunnel through the detection antenna with a single 46-cm diameter opening. Volitional fish passage through the larger antenna opening was markedly improved compared to 1998, when the antenna system consisted of three adjacent, 25-cm diameter openings.

The new system was deployed with the surface trawl and operated for 453 hours from 12 April to 8 June 1999, resulting in detections of 12,132 fish. Sampling effort was increased from 8 to 16 hours per day on 26 April, coincident with the arrival in the estuary of inriver migrants from the Lower Granite Dam transportation study. During the 16-hour sampling periods, respective detection proportions accounted for 2.0, 1.7, and 2.5% of the chinook salmon, coho salmon, and steelhead previously detected at Bonneville Dam.

We detected 1,421 chinook salmon (239 wild) and 1,655 steelhead (236 wild), for a total of 3,076 detections of PIT-tagged fish from the NMFS transportation study. This was the third year that PIT-tagged chinook salmon were transported and the first year that PIT-tagged steelhead were transported, which enabled comparison with similar groups of PIT-tagged fish released for inriver migration.

Chinook salmon and steelhead released from transportation barges downstream from Bonneville Dam remained in the estuary for much shorter periods than their inriver migrant cohorts released at Lower Granite Dam. Only 1.8 days elapsed between the 10th and 90th percentile passage dates of barged chinook salmon detected in the estuary, whereas the 10th to 90th percentile passage dates of inriver migrants differed by 10 days.

Similarly, the respective 10th and 90th percentile passage dates of estuary detection for transported steelhead occurred 1.5 and 2.8 days after release from the barge. For inriver migrant steelhead, the 10th and 90th percentile passage dates occurred 11 and 24 days after release at Lower Granite Dam. This longer passage period through the estuary probably contributed to the greater number of detections for inriver migrant fish than for transported fish.

Travel speed from Bonneville Dam to Jones Beach was significantly higher for inriver migrant chinook salmon and steelhead than for their transported cohorts released from barges immediately downstream from Bonneville Dam. Travel speed was correlated with river flow volume for inriver migrants, but not for barge-released fish. Respective seasonal average travel speeds for inriver migrants and barged fish were 93.7 and 60.2 km/day for chinook salmon, and 97.9 and 80.9 km/day for steelhead.

We conducted diel sampling during three periods on weekly intervals during the peak migration period. During these periods we detected 1,538 chinook salmon and 887 steelhead. Chinook salmon detection rates were significantly higher during darkness, with average detection rates of 15.7 fish per hour during daylight and 21.2 fish per hour during darkness. In contrast, the average daylight and darkness detection rates for steelhead were 12.1 and 4.6 fish per hour, respectively; the difference was significant ($P = 0.001$).

Yearling chinook salmon released for The Dalles Dam spillway study that were not detected at Bonneville Dam arrived in the upper estuary an average of 5.8 hours sooner than their cohorts that were detected at Bonneville Dam. Coho salmon from the same study that were not detected at Bonneville Dam were detected in the estuary an average of 4.4 hours sooner than their cohorts that were detected at Bonneville Dam. Differences in travel time between these groups provide an indirect estimate of the time it takes fish to pass through the Bonneville Dam juvenile bypass systems (detected) vs. the time it takes to pass the dam via turbines or the spillway (undetected). These comparisons illustrate the value of a surface-trawl detection system operating independently from detection systems at hydroelectric facilities.

CONTENTS

INTRODUCTION

First used in the Columbia River Basin in 1985, the PIT tag is composed of a sealed glass cylinder, approximately 2.1 mm in diameter and 11 mm long, containing an integrated circuit attached to a multi-turn coil of fine wire (Destron Fearing 1993). Each PIT tag has a unique code stored in permanent memory at the time of manufacture (Prentice et al. 1990a,b). The tag is usually inserted into the peritoneal or dorsal sinus cavity of a fish, and the code is transmitted when the fish passes within reading range of a PIT-tag detector.

Releases into the Columbia River Basin of juvenile salmonids implanted with passive integrated transponder tags (PIT tags) began in the 1980s (Prentice et al. 1990a). PIT-tag detection facilities have been installed at all federal hydroelectric facilities with juvenile bypass systems in the basin to monitor the downstream passage of these fish (Prentice et al. 1990c). In the mid 1990s, a regional database, the Columbia River PIT Tag Information System (PTAGIS) was established to store and disseminate PIT-tag release and detection data (PSMFC 1996).

Since 1995, releases of PIT-tagged juvenile salmonids have increased to over 500,000 per year. These large annual releases made feasible the development of a mobile PIT-tag detector for deployment in the estuary. In 1995, the National Marine Fisheries Service (NMFS) developed a surface-trawl system for detection of migrating PIT-tagged juvenile salmonids in the Columbia River estuary. Sampling with the trawl system was conducted off Jones Beach, River Kilometer (RKm) 75.

Sampling during the juvenile migration continued in 1996 and 1998 (Ledgerwood et al. 1997, 2000). We anticipated that 1997 would be the year that the 400-kHz PIT tag systems were replaced by 134.2-kHz systems throughout the Columbia River Basin, but the transition was postponed.

There were no plans for deployment of the 400-kHz surface trawl detection system after 1996 until we discovered that the transition year for the 134.2-kHz tags would be delayed until 2000, and that studies using 400-kHz PIT-tags were expected to continue through 1999. Thus, in 1999 we resumed sampling and development of the surface trawl detection system.

In 1999, releases of more than 1.5 million PIT-tagged juvenile salmonids were recorded in PTAGIS (Stein 1996), and we continued to target large groups of PIT-tagged fish released during April-June. Here we report results of sampling with the surface trawl in 1999. Specific objectives of sampling with the surface trawl were as follows:

1) Provide and compare information on migration behavior and timing for fish groups PIT tagged for the NMFS transportation study.

2) Provide estuarine passage dates that allow survival comparisons between adult fish groups that entered the ocean as juveniles at similar times.

3) Document the diel behavior of juvenile salmonids in the estuary.

4) Provide accurate counts, by origin (wild or hatchery), species, and migration history of smolts entering the upper estuary for evaluations of relative vulnerability to predation by seabirds nesting in the middle and lower estuary.

5) Provide survival estimates to Bonneville Dam for various release groups of juvenile salmonids migrating inriver.

STUDY SITE

The study area is characterized by frequent ship and barge traffic, occasional severe weather, and strong tidal and river currents. The ship channel is about 200 m wide and dredged to about 14 m in depth (Figure 1). Deployment of the PIT-tag detector/trawl in the Columbia River occurred between RKm 83, near Eagle Cliff, and RKm 61, near Clifton Channel (Ledgerwood et al. 2000). Tides in the study area are semi-diurnal with about 7 hours of ebb and 4.5 hours of flood. Depending on the time of day and tidal stage during which the net was deployed, the distance that could be traveled downstream with the pair-trawl varied considerably.

During the spring freshet period (April-June), little or no flow reversal occurred in the sample area during flood tide, particularly during the high river flows experienced in 1999. Rarely, and for short periods near peak flood current, were we able to maintain position in the river or actually make upstream headway with the net under tow. Generally, the net and boats moved downstream continuously with drift velocities often exceeding 1.5 m/s (3 knots). Flooding and high water conditions contributed to the debris load in the river, and at times we terminated towing operations earlier than desired to remove debris from the net.

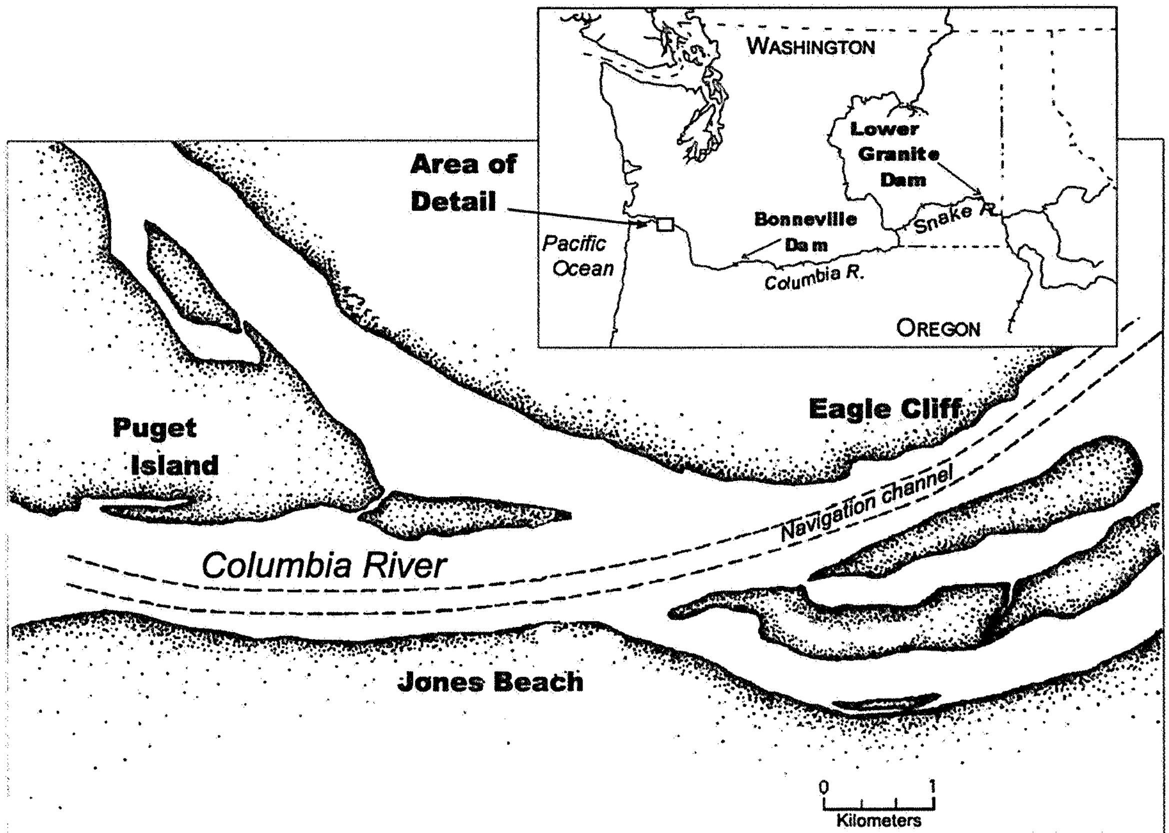


Figure 1. Overview and cross-sectional views of the upper Columbia River estuary sampled with the PIT-tag detector trawl in 1999 (Jones Beach, river kilometer 75).

METHODS

Trawl Design and Vessel Operations

The pair trawl consisted of a 91.5-m wing attached to each side of the 15.5-m body of the trawl containing the PIT-tag detector. Sampling depth was about 4.3 m and the distance between the wings of the trawl was about 91 m when under tow. The detector was located in the exit to the trawl where a cod end is normally positioned (Ledgerwood et al. 2000). Details of trawl construction and vessel operations were similar to previous years.

A 7.9-m pontoon barge bridled to the cork-line near the exit of the trawl was used to house the PIT-tag electronics equipment and the detection antenna itself. A 5.5-m skiff was used to assist in deployment/retrieval operations and to move crew members between vessels as needed.

Detection Antenna Development

In 1998, we had used three adjacent 25-cm-diameter fish passage openings set in a fiberglass housing. The fish passage opening size was limited by the reading range of the detection antennas, which was 12 cm. In 1999 we modified the electronic equipment substantially to further increase the reading range of the antenna, and thus the size of the fish passage opening. These modifications produced an antenna with a single 46-cm diameter opening. Details of the modifications are provided below.

In 1999, we used a new 400-kHz PIT-tag detection system, which included improved electronics and an underwater antenna with a single 46-cm diameter opening (Figure 2). The detection system used in 1998 (Ledgerwood et al. 2000) was also available and served as a backup for the new system. However, the 1999 system was reliable, and the 1998 antenna system was not used in 1999 except during brief test periods at the beginning of the season. Major components of the 1999 detection system were the antenna, the power-interface box, the power amplifier, two signal receiver/converters, and the decoder/controller.

The 1999 surface-trawl detection system combined portions of the newly designed, 400-kHz flat-plate detector system installed at Bonneville Dam, a specially designed 46-cm diameter antenna, and a decoder/controller provided by Destron Identification Devices, Inc. The antenna consisted of three separate coils. The center coil winding was used to create an electromagnetic field (400 kHz) that energizes or excites PIT tags as they pass through the tunnel. The coils on either end were used to receive a PIT-tag-generated modulation of the exciter field.

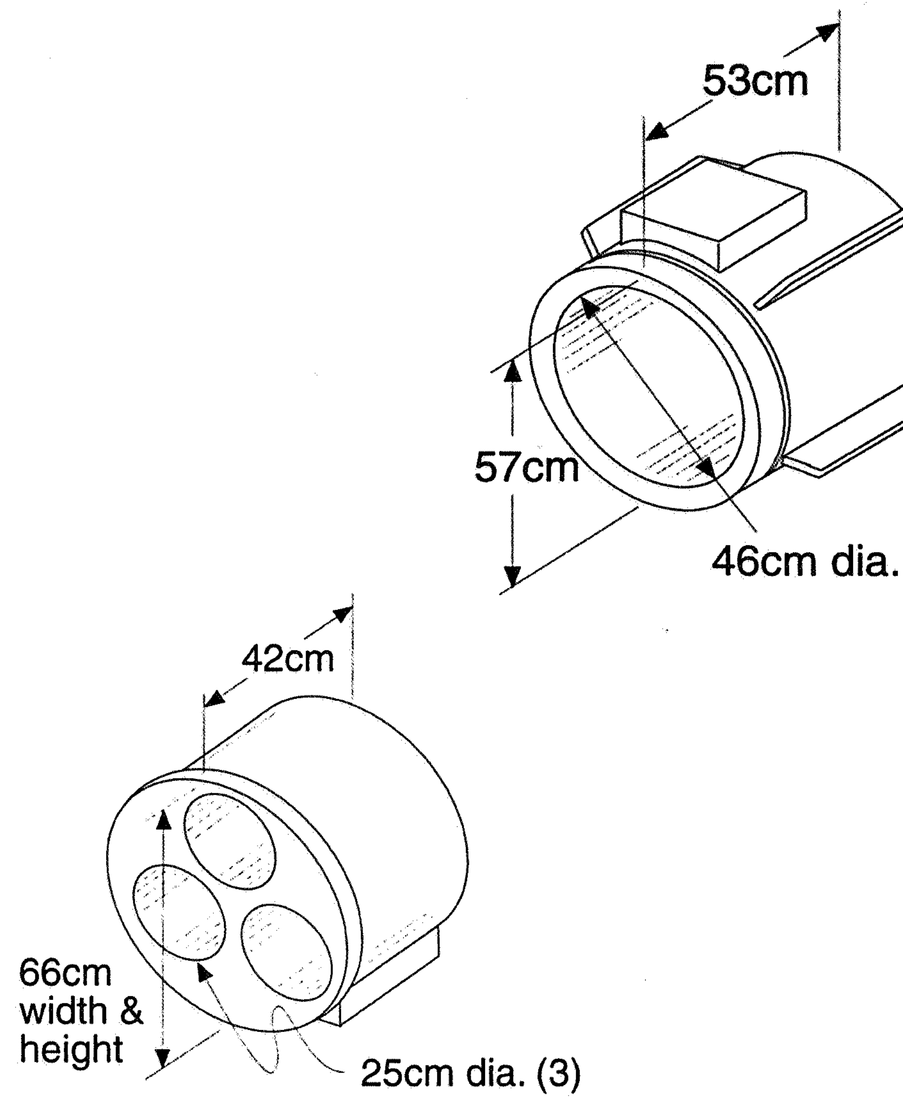


Figure 2. Detection antenna used with the surface-trawl system in 1999 (top right) is constructed with a single 46-cm-diameter fish passage opening with a three-coil antenna wrapped in sequence over the opening. The antenna used during 1998 (lower left) was constructed using three parallel fish passage openings, each wound with a single coil, and each having a diameter of 27-cm. Both systems operated with 400-kHz PIT-tags, and both were housed in water-tight fiberglass.

The antenna was encapsulated in fiberglass to maintain water-tight integrity. A small, water-tight box was molded into the fiberglass to protect the passive exciter and receiving tuning components mounted on the body of the tunnel. A watertight connector mounted on the box provided connections to the system electronics via a 9.1-m long cable. The power interface box generated the 400-kHz signal and contained tuning components used to couple the amplifier output to the antenna with maximum efficiency. The interface box also contained circuitry to measure and display on a front-panel meter the amount of antenna current being coupled to the antenna, and thus provided a visual monitor of system function. Loss of current could indicate antenna damage or leakage into the tuning component box on the antenna.

The power amplifier takes a low-power 400-kHz input signal from the power-interface box and amplifies it to about 20-50 watts. Two signal receiver/converters demodulate PIT-tag signals from the 400-kHz exciter signals received from the upstream and downstream receiving-antenna coils. PIT tags modulate the 400-kHz exciter frequency with 40- and 50-kHz tones, which represent high or low bits in a specific code pattern preset into each tag.

The converters extract these tones and conduct them to the decoder/controller. The receiver/converters were tuned during initial system setup, and no field adjustments were possible. Finally, the decoder/controller received low-level tone signals from the receiver/converters, decoded tag information into a binary form, and reformatted the data. The decoder then added controller and antenna receiving-coil identification codes and a time stamp to each detection record and transmitted the data to a computer for logging via an RS232 cable.

Target Fish

In 1999, principal fish targeted for the research were the nearly 125,000 PIT-tagged juvenile spring/summer chinook salmon and 115,000 juvenile steelhead released at Lower Granite Dam on the Snake River (RKm 695) or transported and released in the Columbia River 9 km downstream from Bonneville Dam (RKm 234). These fish were released from April through mid-June to compare survival between inriver migrating and barge-transported fish (Marsh et al. 1996). Fish used for the transportation study represented about 10% of the daily total of smolts migrating through the bypass system at Lower Granite Dam. Both wild and hatchery reared fish were used in the transportation study.

Total numbers of target fish included those from the transportation study (over 240,000 tags; Marsh et al., 1996, 1997, 1998, in prep.); the Snake River Hatchery Comparative Survival Study (over 224,000 tags; Berggren and Basham 2000); The Dalles Dam spillway survival study (over 139,000 tags; Dawley et al. 2000); and survival studies conducted at hydroelectric facilities on the mid-Columbia River (Bickford et al. 2000a,b).

Data from the estuary detections were also compared with detections of PIT tags from the large colonies of Caspian terns (*Sterna caspia*) and double crested cormorants (*Phalacrocoras* spp.) on estuarine islands downstream from Jones Beach (Ryan et al. 2001).

Descaling and Injury Assessments

Assessments of descaling and injury of fish passing through the surface trawl and detector were accomplished in several ways. In 1998, about 100 fish traversing the detector system were sampled approximately weekly to assess descaling and injury rates using a sanctuary-bag recovery net attached to the back of the detector box (Ledgerwood et al. 2000).

However, in 1999 the larger diameter of the detector allowed additional flow into the sanctuary-bag of the recovery net, and divers observed that the increased flow created turbulence that impinged salmonids on the walls of the sanctuary-net, particularly the smaller fish. Thus fish were descaled by the sampling device itself, invalidating the sample results, and after a few attempts the sample effort was discontinued.

We continued to observe fish passage through the detector on a video monitor using a camera mounted inside the cod end of the trawl just forward of the detector. When debris accumulation or other potential problems were observed on the monitor, the trawl was brought down to idle speed and the cod end pulled up for cleaning. If debris load in the trawl became troublesome, we disconnected the electronics, inverted the net to clean the debris, and re-deployed the system. As in previous years, we recorded all observances of fish impinged, gilled, or otherwise entrapped in the netting. Divers also periodically assessed the net and detection system during deployment.

Sampling Period

Sampling began on 12 April and continued through 8 June, coincident with the passage of PIT-tagged fish from the transportation study. Beginning on 26 April, sampling increased from a single daily sampling crew to two daily crews. The two-crew effort was maintained until 4 June, when detection rates declined and we returned to a single daily work crew. Generally, one work crew began before daylight and sampled for an 8 to 10 hour period, and a second crew began in late afternoon and sampled until dark. On three occasions during the middle of the season we conducted extended sampling cruises, where sampling was continuous except for brief periods of net cleaning and when it was necessary to retrieve the net to move the operation upstream. Tow vessels were rotated out of the operation for refueling during these cruises.

Data Monitoring and Recording

A 9.1-m-long cable leading from the surface was attached to the tuner port of the detection tunnel and a 3,500-watt gas-powered generator provided power for all electronics. General system operation and maintenance was fairly straight-forward. The exciter/reader boxes, and all other electronic equipment, were kept dry and protected from mechanical damage and were installed in a location having adequate ventilation for cooling. Special attention was required to the underwater antenna assemblage to prevent damage to cables and cable sheaths by crimping.

Once the detector was energized, most operations were automatic. A DOS-based computer software program (Monitor.exe) and printer automatically recorded and printed detection data. We also maintained a written log of times and duration that the detector was energized, the total number of detections, and diver observations. Though the new detection system was not equipped with automatic test circuitry, we were able to test the system using a PIT tag taped to a stick, which we passed through the detector.

We recorded Global Position Satellite (GPS) readings of the tow vessel at the beginning and end of each deployment and occasionally during deployment. These position recordings are available to track the approximate location of individual PIT-tagged fish by matching the date and time from the detection record to the date and time of the GPS positions.

The PTAGIS database was used as a repository for all interrogation information recorded with the PIT-tag detector/trawl equipment. The unfiltered and unedited interrogation data files required by PTAGIS were uploaded to the database periodically during the sampling season using standard procedures via modem (Destron Fearing 1993; Stein 1996). Detections obtained using the PIT-tag detector/trawl were identified in PTAGIS using the interrogation site code "TWX" (towed array).

We also maintained an independent database (Microsoft Access) of our interrogation data to facilitate analysis and to compair our estuarine detection data with matching release information available through PTAGIS. For detections of barged fish from the transportation study, we modified the PTAGIS release information within our database to reflect the date, time, and RKm where transportation barges were emptied of fish downstream from Bonneville Dam (the PTAGIS release data represent the approximate date/time/RKm that the fish were placed into the raceways at Lower Granite Dam prior to loading onto transportation study barges). Data for fish released from the transport barges was provided by the U. S. Army Corps of Engineers (Michael Halter and David Hurson, Personal communication; Appendix Table 1).

PIT-tag interrogations recorded by detectors at Bonneville Dam during the 1999 study period (over 130,000 fish) were also accessed and downloaded from PTAGIS. These detections were compared against detections at Jones Beach to evaluate travel time from Bonneville Dam to the upper estuary sampling area. Detections in the upper estuary that came from fish never previously detected were used for estimates of survival to Bonneville Dam.

Statistical Analysis

Volitional fish passage through the single 46-cm diameter detector used in 1999 was compared to the 3-pipe, 25-cm diameter, detector used in 1998. Volitional passages were defined as those detections occurring before or after the net "flushing" procedures, whereas non-volitional passages were defined as detections that occurred during flushing procedures. For these analyses we selected detection data from the three diel sampling periods in each respective sample year and divided those data into two groups according to daylight and dark hours.

For the purpose of separation, the onboard logbooks were inspected and fish detections recorded between 3 minutes following the radio-call for a net flush until 3 minutes following the radio-call for a net open were considered non-volitional detections. This 3-minute delay was necessary to allow for time to position the trawl. Fish detected outside of this restricted time period were termed volitional detections. The proportions of fish detected in each volitional or non-volitional category using antenna design and diel period as factors were analyzed using analysis of variance (ANOVA). Plots of residuals appeared normal so that no transformations of percentages were needed.

Diel patterns (number detected per hour during daylight hours compared to dark hours) for yearling chinook salmon and steelhead were evaluated using one-way ANOVA (Zar 1999). The number of detections and the minutes within each hour that the detector was energized for each of the three diel sampling periods were separated into daylight- and darkness-hour categories, and mean hourly detection rates were pooled for wild and hatchery rearing types of each species for each sampling period.

We used logistic regression (Hosmer and Lemeshow 1989) to compare detection percentages among various release groups that passed the upper estuary during our trawling period. Comparisons were made among groups released at Lower Granite Dam for inriver migration and groups transported in barges and released downstream from Bonneville Dam. Additional comparisons were made by species (yearling chinook salmon and steelhead) and rearing history (wild and hatchery). We obtained daily release data for fish within each category of interest from PTAGIS and matched data to the estuary detections. To ensure adequate sample sizes, we pooled adjacent release days until we had a minimum of five detections from each release group.

We plotted travel time distributions and compared detection rates for three subsets of transportation study fish marked at Lower Granite Dam and detected in the estuary: inriver migrants detected at Jones Beach, inriver migrants detected at both Bonneville Dam and Jones Beach, and transported fish released just downstream from Bonneville Dam and detected at Jones Beach.

Multiple linear regression was used to evaluate differences in travel speed to Jones Beach between inriver migrants and transported fish. Multiple regression analysis was also used to test the null hypothesis that there was no difference in travel speed to Jones Beach following detection at Bonneville Dam among PIT-tagged fish released at The Dalles or Lower Granite Dam. The alternative hypothesis was that travel speed to Jones Beach following detection at Bonneville Dam was related to distance at release.

Factors used in the regression models of travel speed included Julian date, flow, and migration history (inriver migrant vs. transported), and two-way interaction terms for the three main effects. Flow data were daily average discharge at Bonneville Dam (ft^3s^{-1}). The interaction terms for Julian date and flow were not significant and were removed from the models. The travel speed data were presented graphically showing 5-day mean values, but all regression analyses were performed using data from individual fish. We used multiple regression analysis to compare fork length (mm) at tagging to travel time to Jones Beach for several major release groups not tagged in the fall of the previous year. Factors used in the regression model of travel time included fork length, flow, and release site.

The periods of availability in the estuary for wild and hatchery yearling chinook salmon and steelhead released from barges downstream from Bonneville Dam, detected at Bonneville Dam, or released farther upriver (at Lower Granite Dam) were compared using analyses of travel time distributions. Travel time (in days) to the estuary was calculated for each fish by subtracting date and time of release (at location of release or detection at Bonneville Dam) from date and time of detection at Jones Beach.

Travel time distributions for release groups of interest were compared using the 10th through 90th percentiles and the middle 80th percentile range. These two sets of statistics characterize the location, width, and shape of the distributions. Standard errors were estimated using bootstrap resampling techniques (Efron and Tibshirani 1993). For each data set, 1,000 bootstrap samples of individual tagged fish were obtained by sampling with replacement from the original data set. Each bootstrap sample was the same size as the original data set.

Calculations of the 10th to 90th percentiles (by 10s) and the middle 80th percentile were applied to each bootstrap sample, resulting in sets of 1,000 bootstrapped estimates for each of these statistics. We chose 1,000 samples to obtain reasonable variance estimates (Efron and Tibshirani 1993). The standard error for a particular statistic was calculated as the standard deviation of the 1,000 bootstrapped estimates. To compare two particular distributions, the differences between the respective percentiles and middle 80th percentile was calculated and compared using a two-sample t-test ($\alpha = 0.05$; Zar 1999).

Binary logistic regression was used to test the hypothesis that there were no differences in estuary detection rates between wild and hatchery fish previously detected at Bonneville Dam (detection rates for yearling chinook salmon released at The Dalles Dam were compared to those released at Lower Granite Dam). A similar analysis was performed to test the hypothesis that there were no differences in estuary detection rates between yearling chinook salmon and steelhead released at Lower Granite Dam and those detected at Bonneville Dam.

For these analyses, detections recorded at Bonneville Dam were downloaded from PTAGIS to our database, and a binary coding scheme was applied to the data: records of fish detected both in the estuary and at Bonneville Dam were coded with a "1" and those detected only at Bonneville Dam coded with a "0." Bonneville Dam detection data were also selected to match dates of intensive estuary sampling. Models included Julian date of detection at Bonneville Dam and species or release site and the interaction terms. Seasonal trends in detection percentages were presented showing 5-day averages.

We used a single-release mark-recapture model (Cormack 1964; Skalski et al. 1998; Muir et al. 2001) to calculate survival probabilities from release at Lower Granite Dam or detection at McNary Dam to Bonneville Dam for a variety of inriver migrating fish groups. Allowing 2 days for migration from Bonneville Dam to Jones Beach, we selected fish detected at Bonneville Dam between 24 April and 2 June.

Seasonal average survival was estimated for yearling chinook salmon and steelhead migrating inriver from the Snake and mid-Columbia Rivers. Estimates were obtained using component reach survival probabilities for migration from Lower Granite Reservoir to McNary Dam and from McNary Dam to Bonneville Dam (Iwamoto et al. 1994; Williams et al. 2001). PIT-tag detection data from the estuary provided a minor contribution to estimates of survival probability from Lower Granite Dam to McNary Dam. However, they were essential to estimates of survival to Bonneville Dam from any upstream release site.

The single-release model used to estimate survival for inriver migrants to Bonneville Dam assumes that the probability of estuary detection for fish not detected at Bonneville Dam was equal to that of fish detected at the dam. To examine this assumption, we used multiple linear regression to compare travel time to Jones Beach for PIT-tagged fish released at The Dalles Dam and detected or not detected at Bonneville Dam. We pooled detection data for consecutive days until we had a minimum of five fish in each comparison group, and then we averaged the travel times for the groups.

RESULTS

The PIT-tag detector/trawl was deployed and operational for a total of 453 hours between 12 April and 4 June (Figure 3). During this period, 12,132 PIT-tag detections were recorded, not including test tags, duplicate tag records, or records resulting from "bit-shift" phenomena (Appendix Table 2). Estuarine detections were recorded for 7,373 chinook salmon, 421 coho salmon, 78 sockeye salmon, and 4,114 steelhead. In addition, 146 detections had no release information in the PTAGIS database.

Volitional Fish Passage

The new PIT-tag detection system proved reliable electronically and was used almost exclusively throughout the sampling season (the 3-pipe detection antenna used in 1998 was used briefly for backup and test purposes in 1999). The larger opening of the 1999 system allowed more water (and debris) through the exit than the 3-pipe system. Tow speed of the trawl was similar both years, about 0.7 m/s (1.4 knots), using the same boats both years and towing at 1,300 engine RPM. Fish observed on the underwater video camera appeared to readily exit through the larger antenna opening in 1999 compared to the more restricted and delayed passage observed at the entrance to the 3-pipe detector in 1998.

Most detections occurred when the wings of the trawl were brought together to flush fish through the detection antenna at the cod end. Volitional passage, defined as the proportion of detections recorded while the net was not being flushed, was greater during darkness than daylight hours. This suggests that visual cues affected fish behavior in passing through the detector openings. For chinook salmon, volitional passage increased from 10% during daylight to 23% during darkness in 1998 and from 23% during daylight to 46% during darkness in 1999. For steelhead, volitional passage increased from 7% during daylight to 62% during darkness in 1998 and from 19% during daylight to 39% during darkness in 1999. However, the increase in volitional passage for steelhead during darkness was not significant because too few fish were detected during darkness hours in 1998 for meaningful comparison ($n = 13$; $P = 0.08$).

Descaling, Injury, and Mortality

Descaling and injury rates of fish traversing the detector system were assessed using a sanctuary-bag recovery net attached periodically to the back of the detector box (Ledgerwood et al. 2000). We recovered 417 juvenile salmonids with the sanctuary net; 13.4% were descaled, 1 fish had an injury, and there was 1 mortality (Appendix Tables 3 and 4). We stopped using the sanctuary bag collection after 14 May, when it was

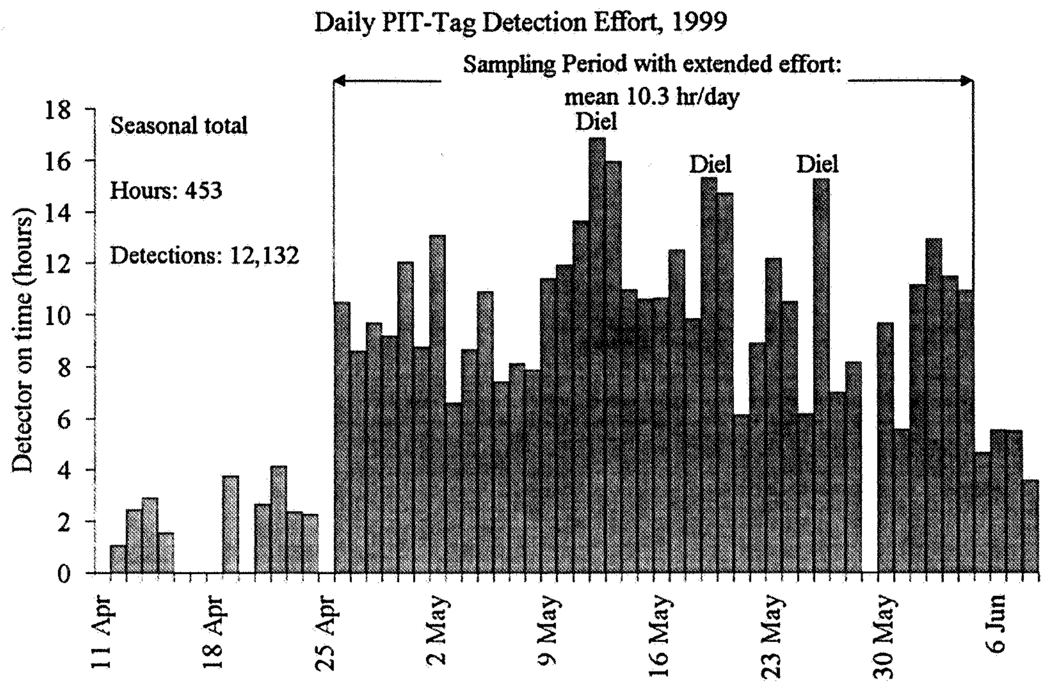


Figure 3. Daily detector on times (hours detector energized) during PIT-tag detector trawl sampling, 1999. The system operated for a total of 453 hours during 1999 detected 12,132 PIT tags. Extended sampling cruises were conducted through day and night periods on during 12-13, 19-20, and 26-27 May.

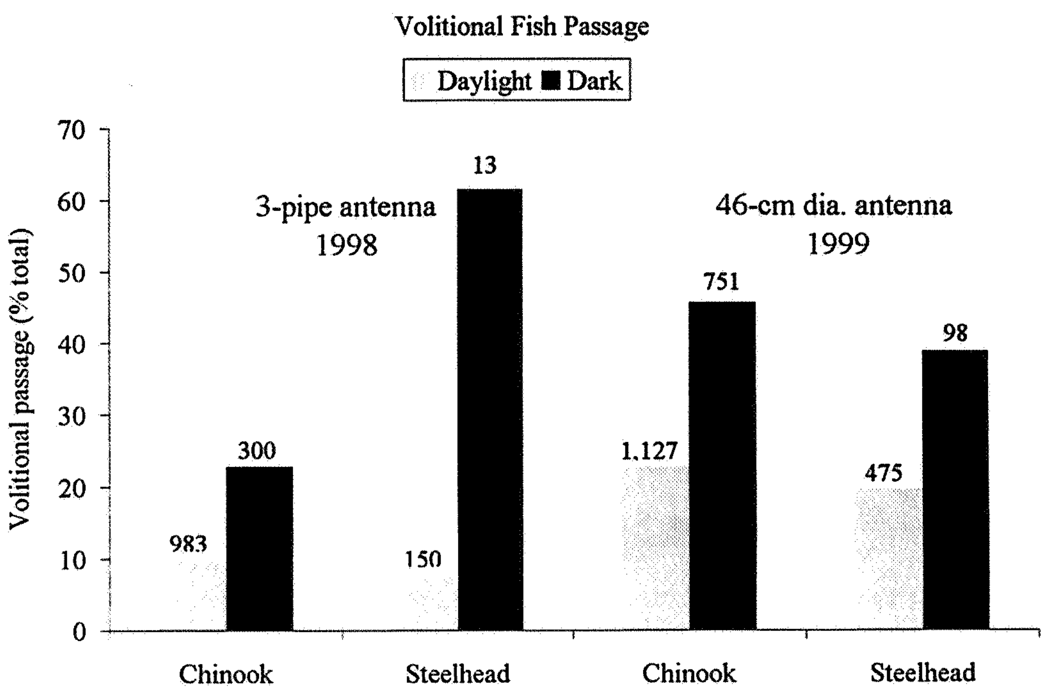


Figure 4. Volitional fish passage rates comparing the average percentage of PIT-tag detections obtained during three diel sampling periods in 1998 (3-pipe detector) and 1999 (46-cm single pipe detector). Volitional fish passage was defined as fish detected during periods with the pair-trawl held in the normal open non-flush configuration; number of fish in each average listed above the bars.

apparent to divers that more flow was entering the collection net through the 46-cm tunnel than the net could disperse. Fish (especially smaller ones) became impinged in the collection net as the excess flow exited through the side webbing. This impingement undoubtedly increased stress and probably contributed to descaling and injury of the sampled fish. Thus use of the collection net was invalided as a means to evaluate passage through the trawl and detector.

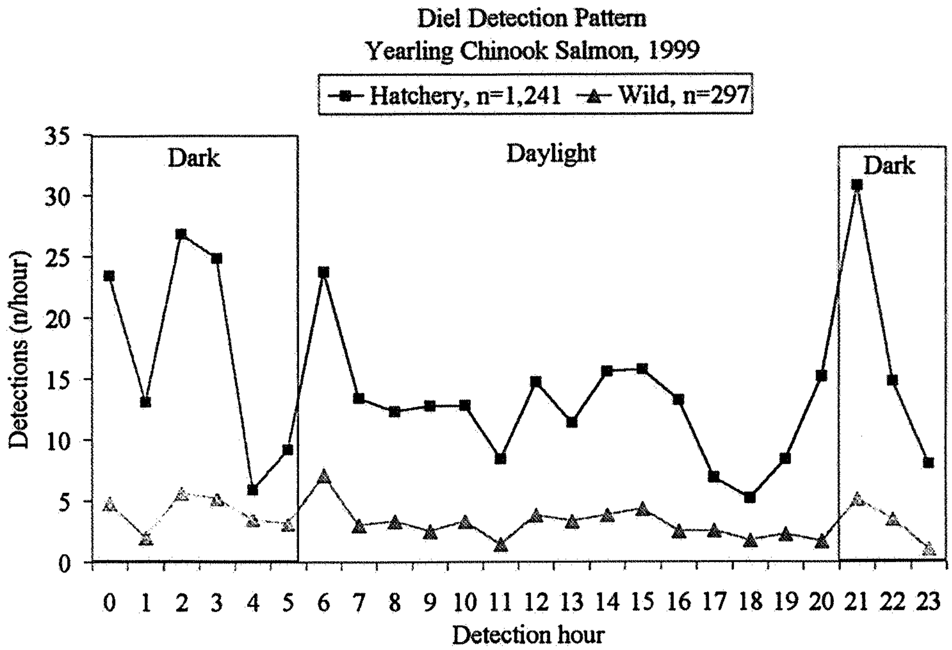
We continued observation of fish near the exit to the detector using video cameras. These nearly continuous (daylight) observations were a preferred method to evaluate potential adverse impacts to fish associated with passage through the trawl and detection system. Obstruction to passage by debris, as evidenced by the video camera, was a periodic problem. We routinely pulled the detector to the surface to remove debris. On a few occasions we were forced to detach the electronics, retrieve the net, and move upriver for re-deployment due to debris conditions.

In addition to fish collected in the sanctuary-bag recovery net, 1,127 salmonids were recovered from the trawl upon retrieval, recovered during debris removal procedures, or observed by divers to be impinged or entrapped in the net underwater. During the debris removal activities, we recorded any impinged or trapped fish as mortalities. It is possible that other mortalities and injuries to fish occurred but were unobserved due to the net inversion process used to clean debris and to release live fish from between the wings prior to net retrieval.

However, divers periodically inspected the trawl body and wing areas of the net not visible by video camera, and only rarely observed fish swimming close to the webbing except near the cod end and detector. Fish tended to pace (swim with) the net near the entrance to the trawl body and directly in front of the detector. In previous years, we eliminated web size and color transitions in the trawl body and cod end that appeared to provide an area of attraction to fish and to delay their passage out of the net.

Diel Detection Patterns

We extended PIT-tag trawling into dark hours during three roughly continuous 36-hour periods in May. We recorded 2,568 detections of PIT-tagged fish during these diel sampling periods (Appendix Tables 5-6). Hourly detection rates for the three diel periods were averaged to summarize the diel pattern for both juvenile spring/summer chinook salmon and steelhead (Figure 5). Diel sampling results indicated significantly decreased detection rates for steelhead during dark hours and significantly increased detection rate for chinook salmon during dark hours.



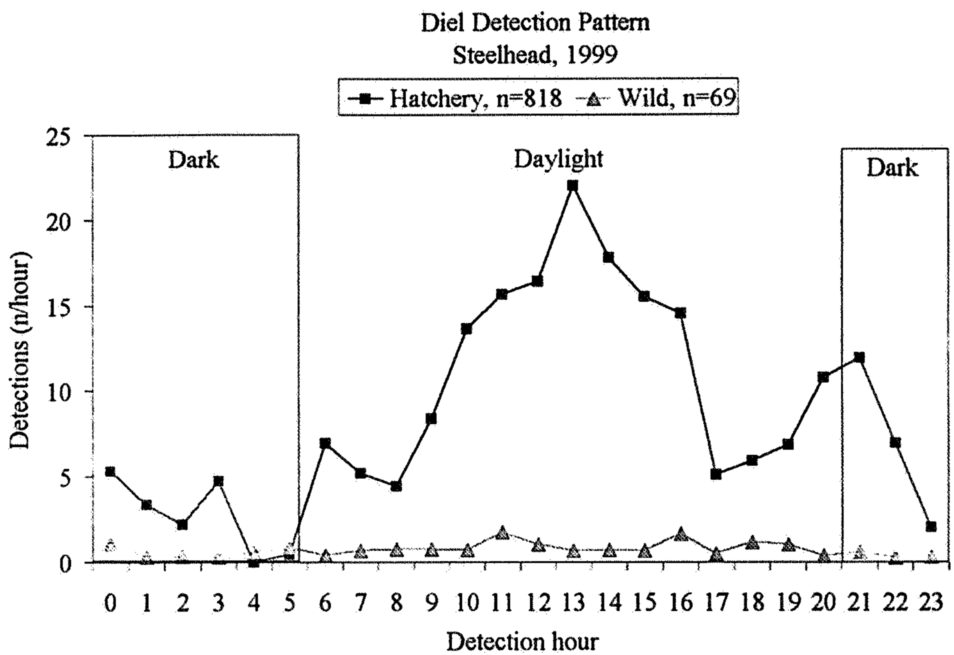


Figure 5. Average diel detection pattern for yearling chinook salmon and steelhead during three diel sampling periods in the Columbia River estuary at Jones Beach, 1999.

For chinook salmon, the average number of detections per hour of detector operation increased from 16.9 during daylight hours to 22.8 during darkness ($P = 0.373$). The average number of detections per hour for steelhead decreased from 12.5 during daylight hours to 4.0 during darkness ($P = 0.140$). There were insufficient detections of wild rearing types during the diel sample periods to allow separate analyses (297 wild yearling chinook salmon and 69 wild steelhead). Detections of juvenile sockeye and coho salmon were too few to provide meaningful comparisons.

In previous sampling, the difference between daylight/darkness detection ratios for chinook salmon varied from significant to not significant (Ledgerwood et al. 1997, 2000). Diel purse seine sampling in 1978-80 at Jones Beach also showed high variability for yearling chinook salmon, and stock differences during different diel sampling periods were thought to have likely contributed to this variability (Ledgerwood et al. 1991). For steelhead, daylight/darkness detection ratios in 1999 were similar to those observed in previous years at Jones Beach (i.e., decreased detection rates during darkness).

Transportation Study Detections

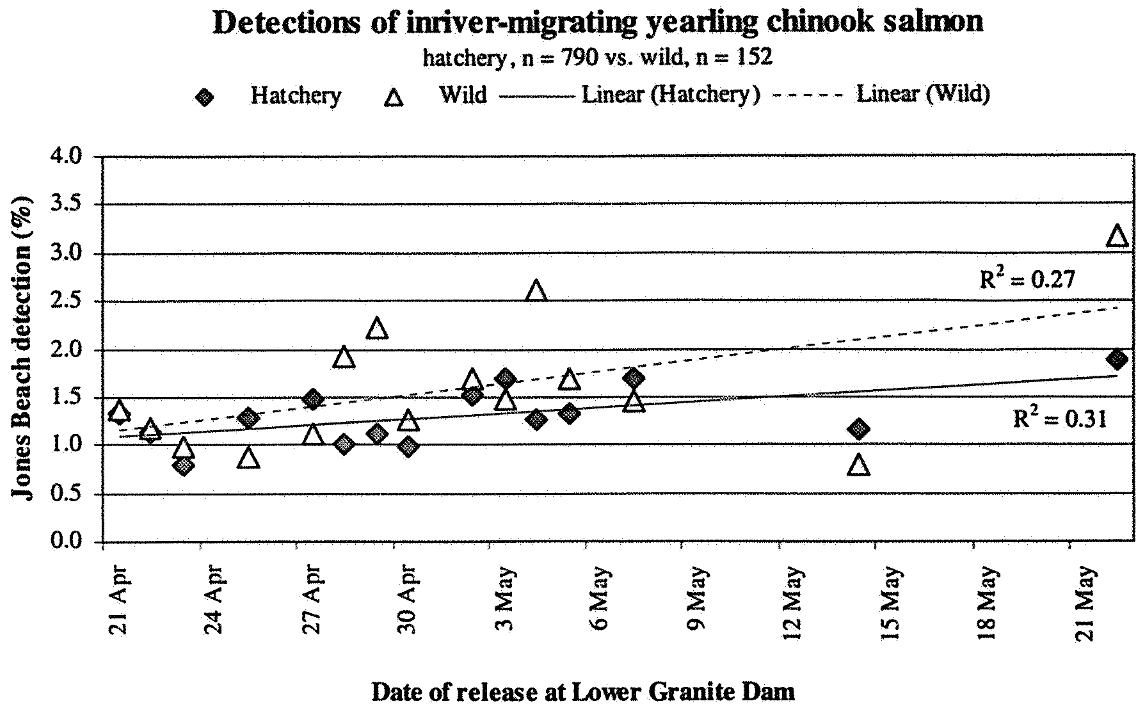
We detected 3,076 PIT-tagged fish released for the Snake River Transportation Study in 1999. Detections included fish released into the tailrace of Lower Granite Dam for inriver migration and those transported by truck or barge from Lower Granite Dam and released downstream from Bonneville Dam (Table 1). This was the first year that steelhead were PIT-tagged for evaluation of transportation from the Snake River and the third year for chinook salmon. Of our total transportation study detections, 1,421 were spring/summer chinook salmon (462 barged fish and 959 inriver migrants) and 1,655 were steelhead (732 barged fish and 923 inriver migrants).

Wild vs. Hatchery Detections

We performed a series of logistic regression analyses to compare detection percentages among wild and hatchery fish from the transportation study release groups that passed the upper estuary during our trawling period (Appendix Table 7). Among yearling chinook salmon released for inriver migration from Lower Granite Dam, no interaction was indicated between release date (covariate) and rear type (wild or hatchery; $P = 0.537$). In the reduced model, differences in detection rate among wild and hatchery fish were nearly significant (mean detection rates were 1.6 and 1.3%, respectively; $P = 0.076$) but release date was a significant factor in the model (Figure 6; $P = 0.005$).

Table 1. Summary of estuarine PIT-tag detections for juvenile spring/summer chinook salmon and steelhead released for the Snake River transportation study, 1999.

Hatchery			Wild			Totals		
	Detected			Detected			Detected	
Released	(n)	(%)	Released	(n)	(%)	Released	(n)	(%)
Yearling chinook salmon								
Transported								
42,015	374	1.08	8,123	88	0.89	50,138	462	0.92
Inriver migrant								
61,289	791	1.36	12,305	168	1.29	73,594	959	1.31
Steelhead								
Transported								
40,671	635	1.56	5,826	97	1.66	46,497	732	1.57
Inriver migrant								
59,776	783	1.31	8,364	140	1.67	68,140	923	1.35



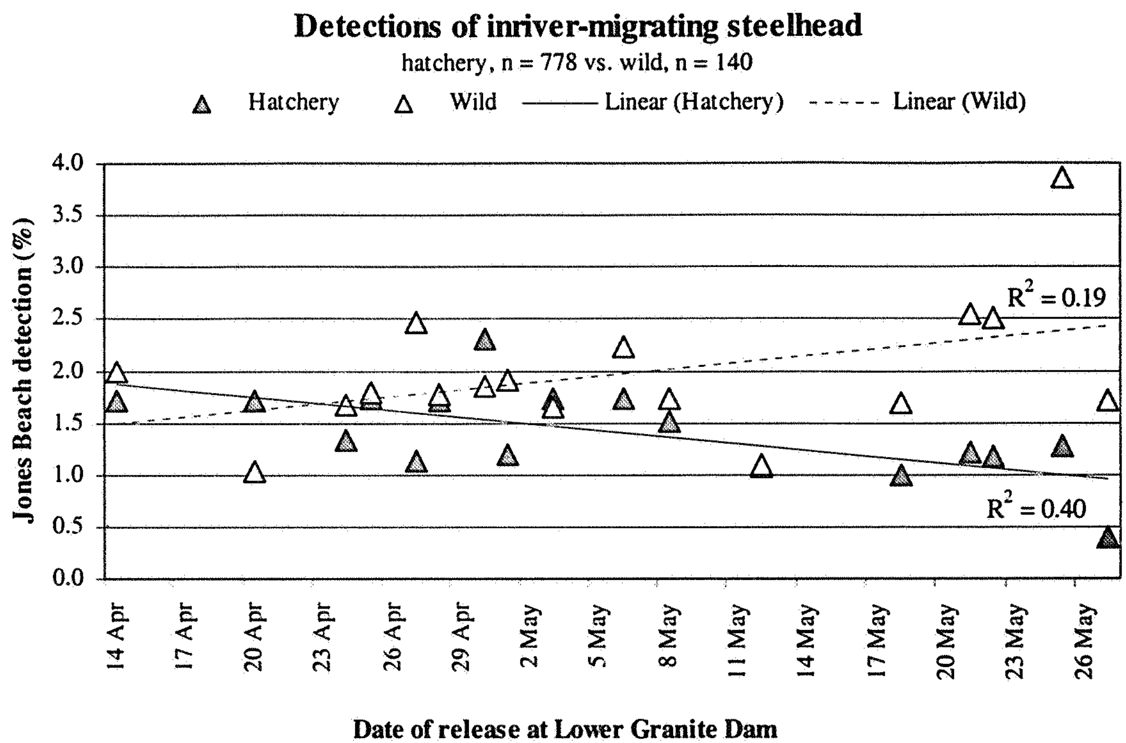


Figure 6. Jones Beach detection rates of hatchery and wild yearling chinook salmon and steelhead released for inriver migration at Lower Granite Dam, 1999.

For inriver migrating steelhead, a significant interaction among release date and rear type was indicated ($P = 0.001$), thus the model could not be reduced. Detection rate for hatchery steelhead decreased from around 2.0% at the beginning of the season to around 1.0% at the end of the season, while detection rate for wild steelhead during the same period increased from about 1.5 to 2.5%.

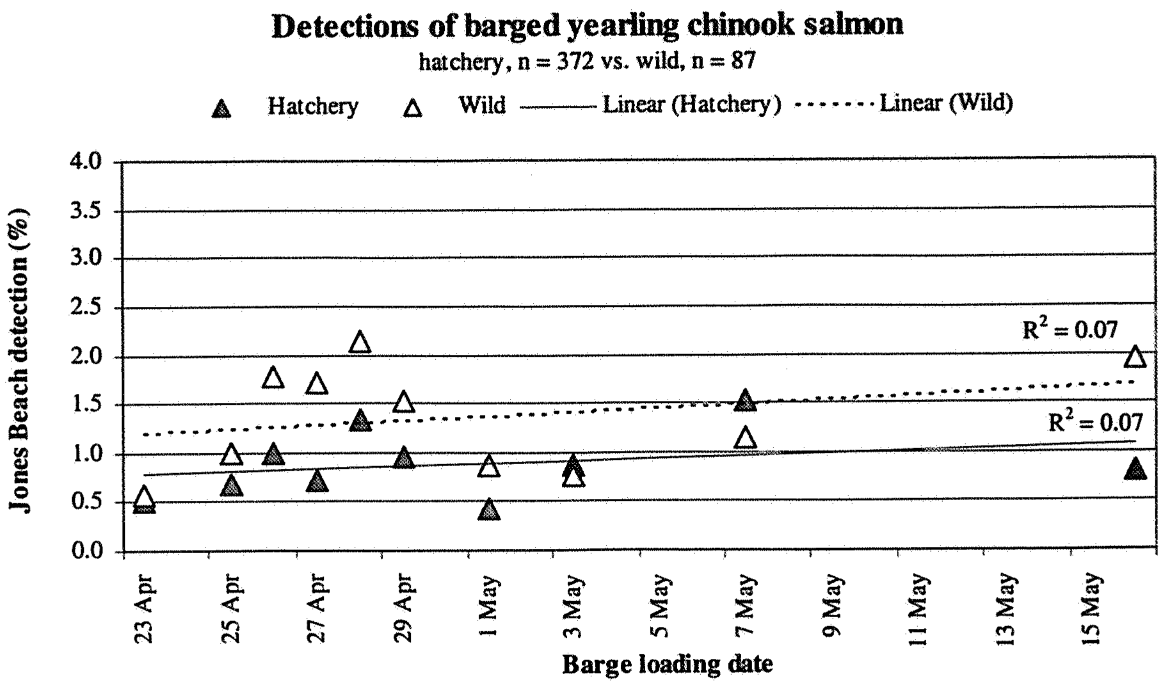
Among yearling chinook salmon transported by barge and released downstream from Bonneville Dam, no interaction was indicated. In the reduced model, wild fish had a significantly higher detection rate than hatchery fish (means 1.3 and 0.9%, respectively; $P = 0.013$) and average detection rates increased from about 0.9% at the beginning of the season to 1.3% at the end ($P = 0.033$; Figure 7). For barged steelhead, no interaction was indicated ($P = 0.604$) and the general linear model indicated no significant difference between wild and hatchery rear types (means 2.7 and 2.1%, respectively; $P = 0.219$). Release date effect was also not significant (Figure 7; $P = 0.189$).

In summary, detection rates at Jones Beach increased from late April through late May for all fish except inriver hatchery steelhead. Wild yearling chinook salmon had higher detection rates than hatchery fish, and wild steelhead had detection rates similar to those of their hatchery cohorts until late in the season, when their detections dropped lower.

Travel Time and Time in the Estuary

Travel time distributions were plotted and compared for the three groups of transportation study fish (Figures 8 and 9). Travel time (in days) was calculated for each fish by subtracting date and time of "release" (at location of release or detection at Bonneville Dam) from date and time of detection at Jones Beach. Travel time distributions for groups of interest were compared using the 10th through 90th percentiles and the middle 80th percentile. These two sets of statistics characterize the location, width, and shape of the distributions.

Standard errors (SE) were constructed using bootstrap resampling techniques (Efron and Tibshirani 1993). For each data set, 1,000 bootstrap samples of individual tagged fish were obtained by sampling with replacement from the original data set. To compare two particular distributions, the differences between the respective percentiles and middle 80th percentile were calculated. We then calculated t-tests as the differences divided by their standard errors (i.e., the square root of the sum of the respective variances). Differences between particular percentiles or ranges among data sets were considered significant if t was greater than 1.96 (the t-value corresponding to $\alpha = 0.05$).



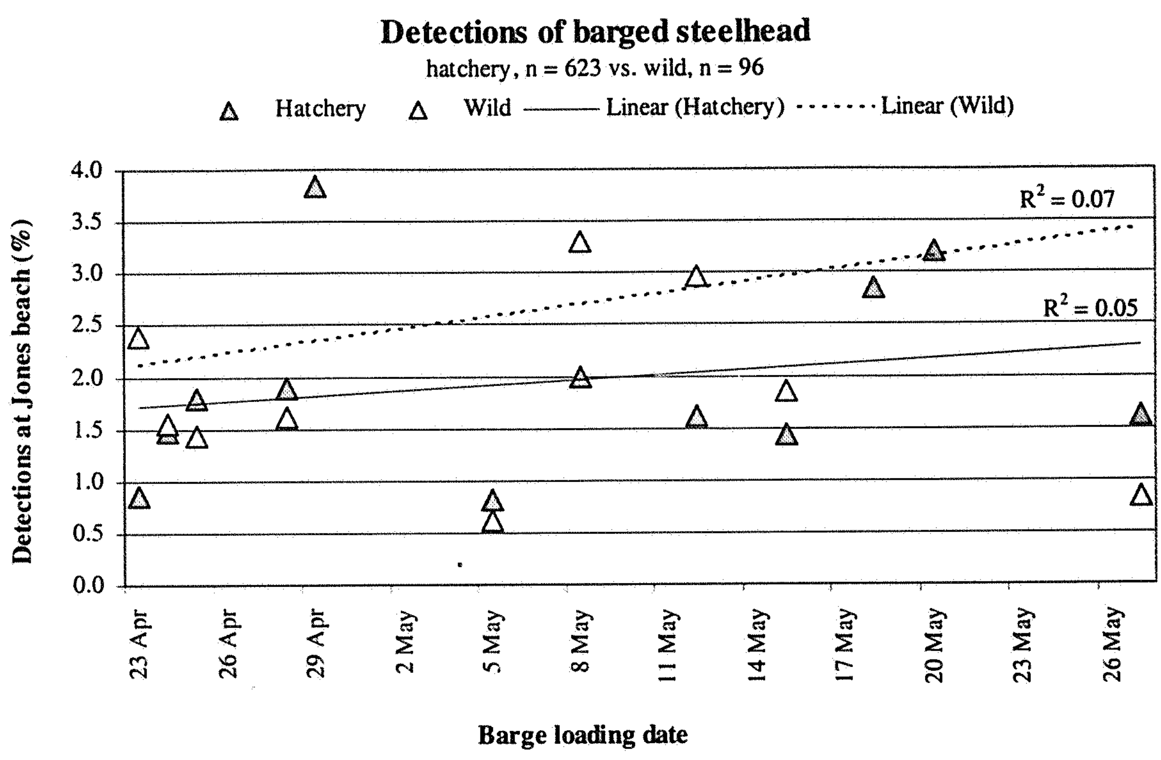
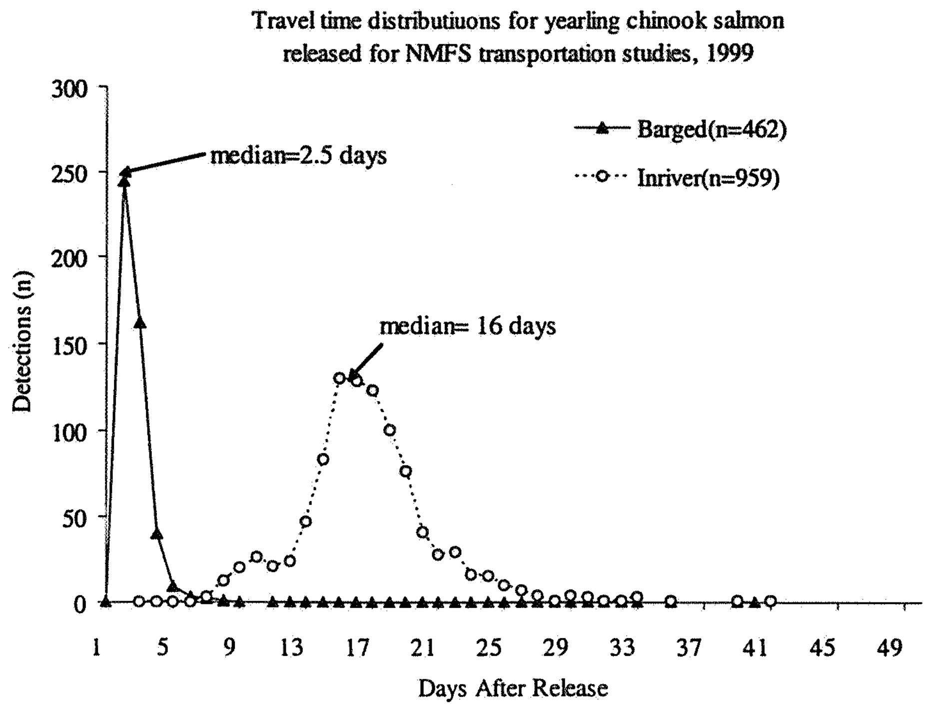


Figure 7. Jones Beach detection rates of hatchery and wild yearling chinook salmon and steelhead transported by barge from Lower Granite Dam and released downstream from Bonneville Dam, 1999.



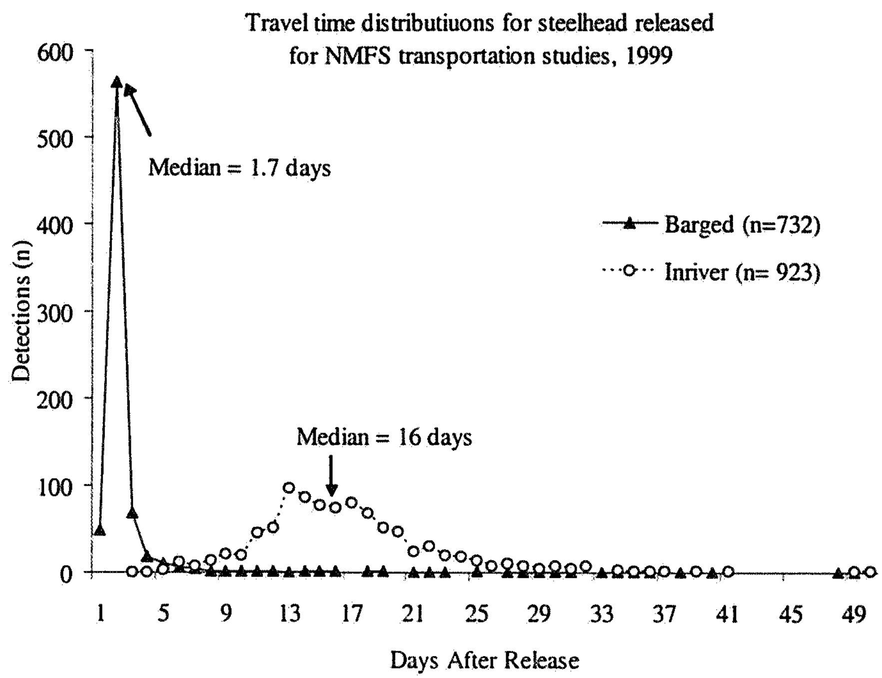


Figure 8. Period of availability in the upper estuary of yearling chinook salmon and steelhead from NMFS transportation study based on the number of days post-release (from Lower Granite Dam or from transport barges) that fish were detected using the PIT-tag detector/trawl at Jones Beach, 1999.

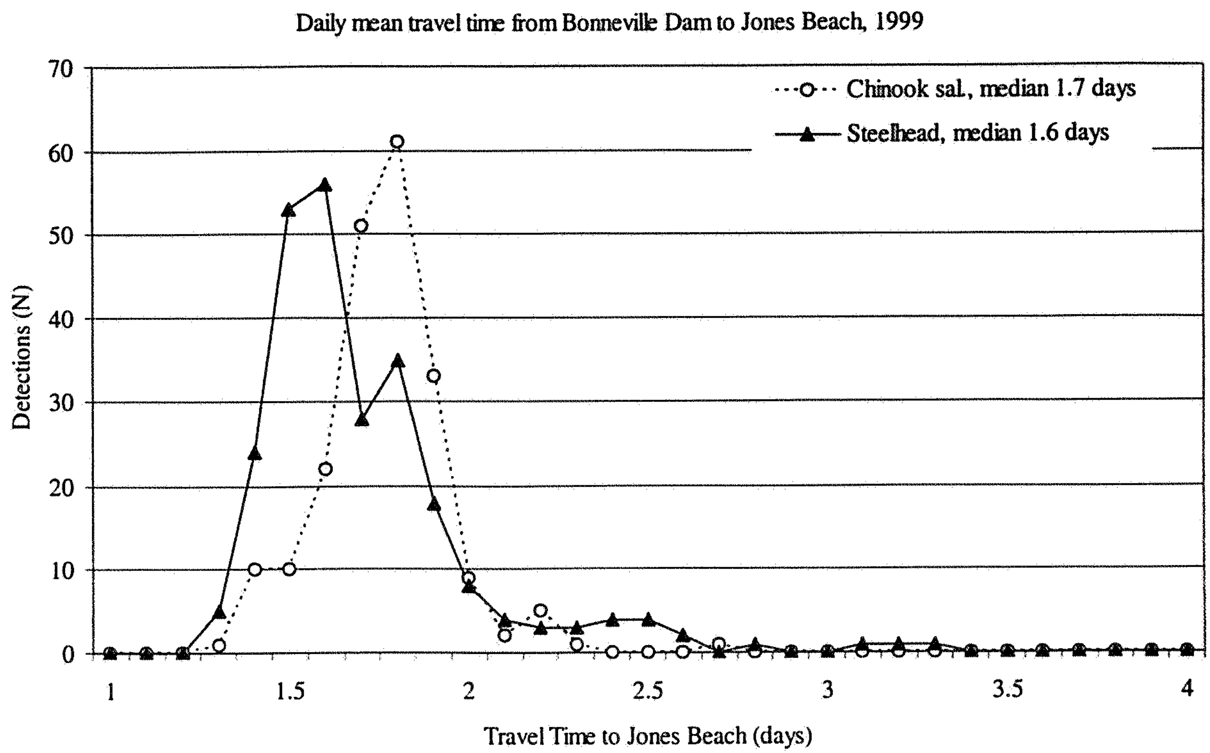


Figure 9. Period of availability in the upper estuary inriver migrant yearling chinook salmon and steelhead previously detected at Bonneville Dam based on travel time from the dam to Jones Beach, 1999.

Inriver Migrants Detected in the Estuary

Wild yearling chinook salmon released at Lower Granite Dam traveled more slowly to the estuary than hatchery fish (difference in median date of detection at Jones Beach was 1.1 days; Appendix Table 8). The opposite held for steelhead: wild fish were faster than hatchery fish (difference in median date of recovery 3.0 days). In addition, wild steelhead had a significantly shorter period of availability at Jones Beach than hatchery steelhead (the middle 80th percentile was 3.7 days shorter).

Wild chinook salmon and wild steelhead had different time periods of availability in the estuary (range difference = 1.8 days), but wild steelhead arrived about 4 days sooner (median difference = 3.8 days; differences in the other percentiles of the distributions were similar). Conversely, hatchery steelhead and chinook salmon had similar passage characteristics through the middle of the distribution (i.e., 10th to 60th percentiles similar), but later in the season, travel time percentiles for steelhead were longer; thus the period of availability at Jones Beach was longer for hatchery steelhead than for hatchery chinook salmon (range difference = 3.9 days).

Inriver Migrants Detected at Bonneville Dam and in the Estuary

Travel time from Bonneville Dam to Jones Beach for inriver hatchery steelhead detected in the bypass system at Bonneville Dam was around 0.1 days shorter than for inriver hatchery yearling chinook salmon through the 60th percentile, but was similar for the later percentiles (Appendix Table 8). Therefore, by arriving in the estuary sooner, hatchery steelhead detected at Bonneville Dam on a given date were available for detection at Jones Beach for a significantly longer time than hatchery yearling chinook salmon (range of difference = 0.3 days). For wild fish the travel time characteristics were similar to hatchery fish but were not significant because of the small sample size for wild steelhead (n = 34).

To help judge the optimal time to sample in the estuary, we examined the median travel times to Jones Beach for inriver migrants detected at Bonneville Dam to project the seasonal average diel availability at Jones Beach for yearling chinook salmon and steelhead detected at Bonneville Dam (Figure 10). Based on the timing of peak passage observed at the dam near dusk, we expected peak passage at Jones Beach to occur near noon for both species.

For yearling chinook salmon, we estimated that 23% of the previously detected fish at Bonneville Dam would pass Jones Beach between 1300 and 1500 hours and between 3 and 6% per hour would pass throughout the remaining hours of the day and night. For steelhead, the projected mid-day peak in availability at Jones Beach was even greater; 52% between 1000 and 1400 hours and less than 5% per hour available during other hours.

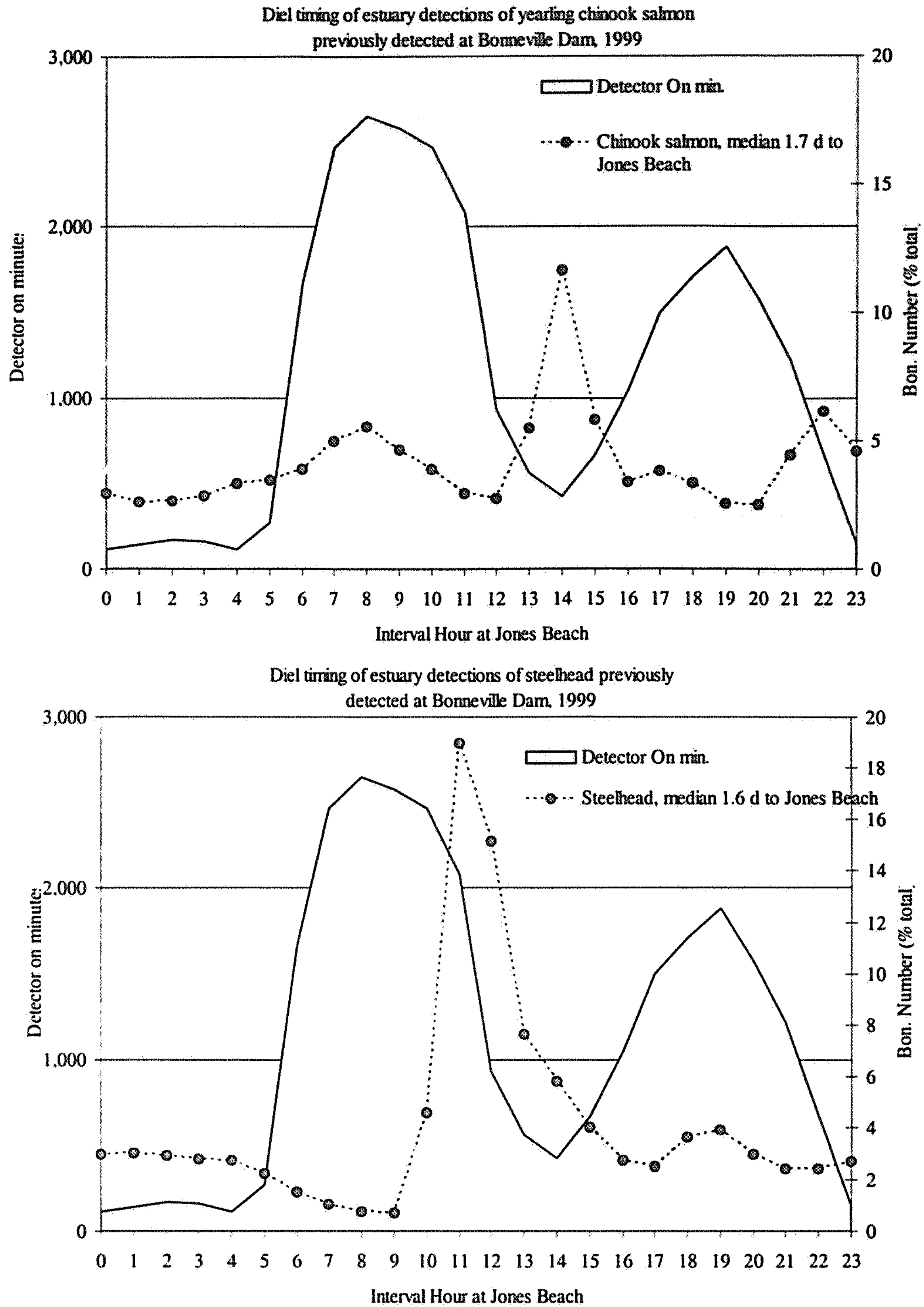


Figure 10. Accumulated seasonal detection effort by hour at Jones Beach vs. projected hourly availability of fish previously detected at Bonneville Dam, 1999. Median travel times used to project hourly availability.

Transported Fish Detected in the Estuary

Travel times to Jones Beach among wild and hatchery yearling chinook salmon released from transportation barges were similar in the middle of the distributions (20th to 60th percentiles) but higher percentiles of hatchery fish were delayed, resulting in an extended period of availability relative to wild fish (range difference = 0.8 days). Differences in travel time distributions for wild and hatchery steelhead released from barges were not significant.

Hatchery steelhead released from barges had shorter travel times to Jones Beach than yearling chinook salmon at all percentiles (median difference = 0.8 days) and were available for a shorter period (range difference = 0.5 days). Wild fish had similar results except that the difference in the duration of the passage period at Jones Beach was not significant (range difference = 0.3 days).

Inriver Migrants Detected at Bonneville Dam vs. Transported Fish Detected in the Estuary

For hatchery and wild yearling chinook salmon and hatchery steelhead, fish released from transportation barges traveled more slowly to Jones Beach than inriver fish detected at Bonneville Dam (differences in median dates of recovery were 0.8, 0.7, and 0.1 days, respectively). Transported fish also had longer period of availability than inriver migrants detected at Bonneville Dam (range differences were 1.5, 0.7, and 0.7 days, respectively). Travel time characteristics of wild steelhead were similar to those of hatchery steelhead but were not significant except for the earliest percentiles (10th to 30th) due both to small sample size and smaller observed differences.

Inriver Migrants vs. Transported Fish Detected in the Estuary

As in previous years, direct comparisons of detection rates between barged fish released downstream from Bonneville Dam and inriver migrants released at Lower Granite Dam were not possible because of differences in distributions and timing past the sampling site. There were significant differences in period of availability at Jones Beach for hatchery and wild yearling chinook salmon and steelhead released from transportation barges and those migrating inriver from Lower Granite Dam (range differences were 7.0, 10.5, 11.4, and 8.7 days, respectively). Respective 10th, 50th, and 90th percentile travel times from release site to Jones Beach for hatchery yearling chinook salmon were 1.9, 2.5, and 3.8 days for transported fish and 12.0, 16.1, and 21.0 days for inriver fish (similar to previous years). For steelhead, these percentiles were 1.5, 1.7, and 2.9 days for transported and 11.4, 16.4, and 24.3 days for inriver fish.

Fork Length vs. Migration Speed

Linear regression analyses were used to evaluate the relationship between size of fish and migration speed for major releases of PIT-tagged fish groups (Table 2). There were no consistent trends between fish length at tagging and travel time to the estuary for any of the release groups; that is, larger fish in a release group apparently did not travel faster than smaller fish. The highest coefficients of determination (R^2) were for yearling chinook salmon released from Carson Hatchery ($R^2 = 0.167$) and steelhead released at Rocky Reach Dam ($R^2 = 0.126$) and Rock Island Dam ($R^2 = 0.106$).

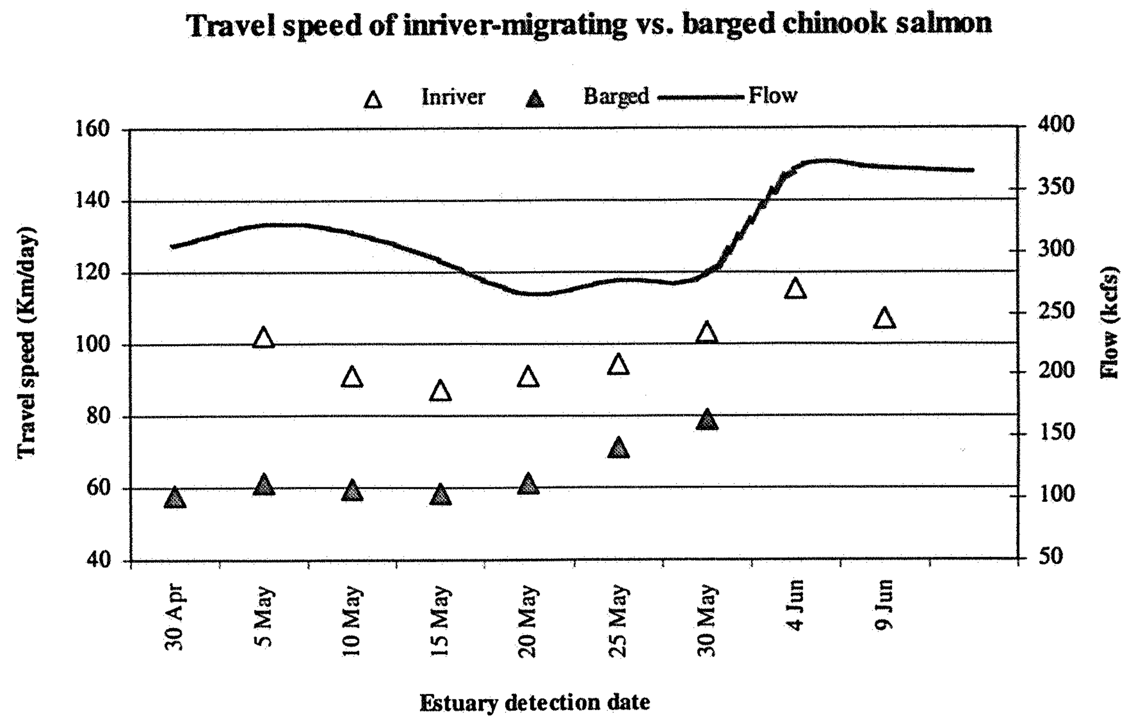
Fork length for the other release groups explained less than 5% of observed variation in travel time (R^2 ranged from 0.000 to 0.025). For the transportation study releases, we also plotted fork length recorded at tagging against detection date in the estuary grouped by week of release (Appendix Figure 1). Again, there was no significant tendency of large fish to migrate faster than small fish.

Overall, we detected about 2% of fish previously detected at Bonneville Dam during the period using two daily sampling crews (Table 3). Unlike previous years, there were no releases and subsequent tracking by other researchers of radio-tagged juvenile salmonids from Bonneville Dam to the study area in 1999 to compare to PIT-tagged fish detected at Bonneville Dam.

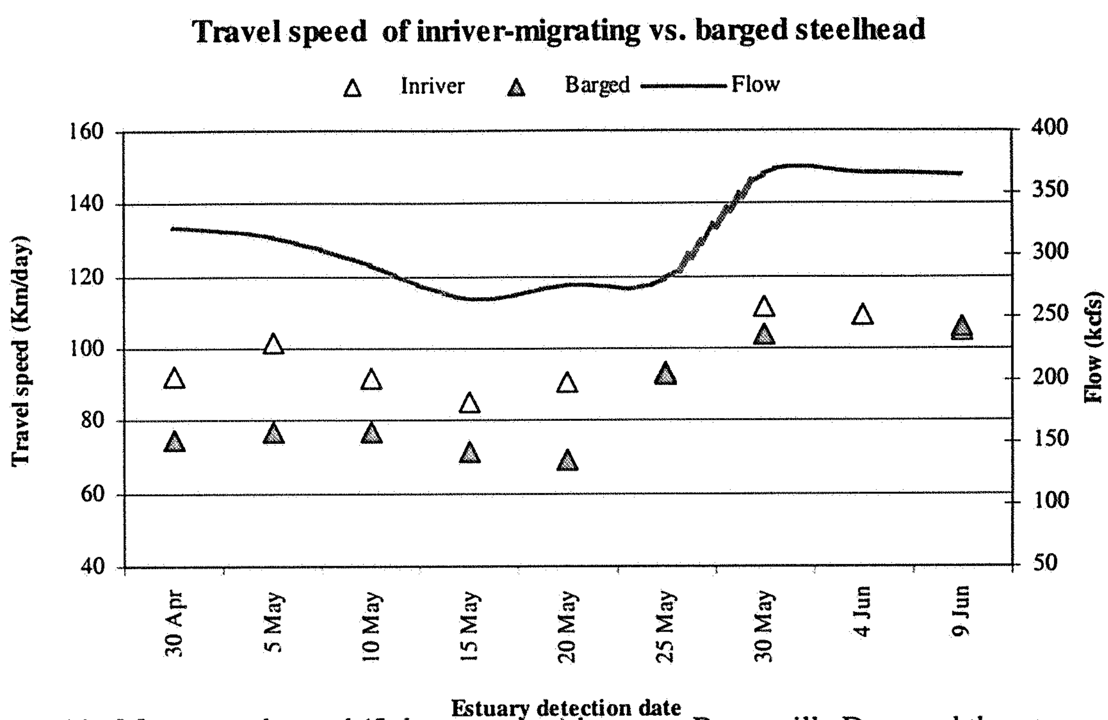
Travel Speed Comparisons

Travel speed to Jones Beach from below Bonneville Dam was faster for inriver migrant chinook salmon (median 92.5 km/day) than for barged chinook salmon (median 60.4 km/day; Figure 11a). There were significant interactions among group and flow ($P < 0.034$) which complicated the analyses; the resulting regression model explained only 64% of observed variation in travel speed.

Travel speed to Jones Beach from Bonneville Dam for inriver migrant steelhead (median 100.5 km/day) was faster than for barged steelhead (median 88.8 km/day; Figure 11b). There was a significant interaction among group and Julian date of detection at Bonneville Dam ($P < 0.001$), which complicated the analyses; the resulting regression model explained only 33% of observed variation in travel speed. Travel speed to Jones Beach following detection at Bonneville Dam for inriver migrant yearling chinook salmon released at Lower Granite Dam (median 92.5 km/day) was significantly faster than travel speed to Jones Beach following detection at Bonneville Dam for yearling chinook salmon released at The Dalles Dam (median values 88.8 km/day; $P < 0.001$, Figure 12). The regression model containing Julian date, flow, and group explained about 53% of the observed variation in travel speed. Interactions among terms of the regression model were not significant ($P > 0.05$).



a)



b)

Figure 11. Mean travel speed (5 day averages) between Bonneville Dam and the upper estuary at Jones Beach for yearling chinook salmon and steelhead. Inriver fish were those detected at Bonneville Dam; transported fish were released just downstream from the dam for NMFS transportation study, 1999.

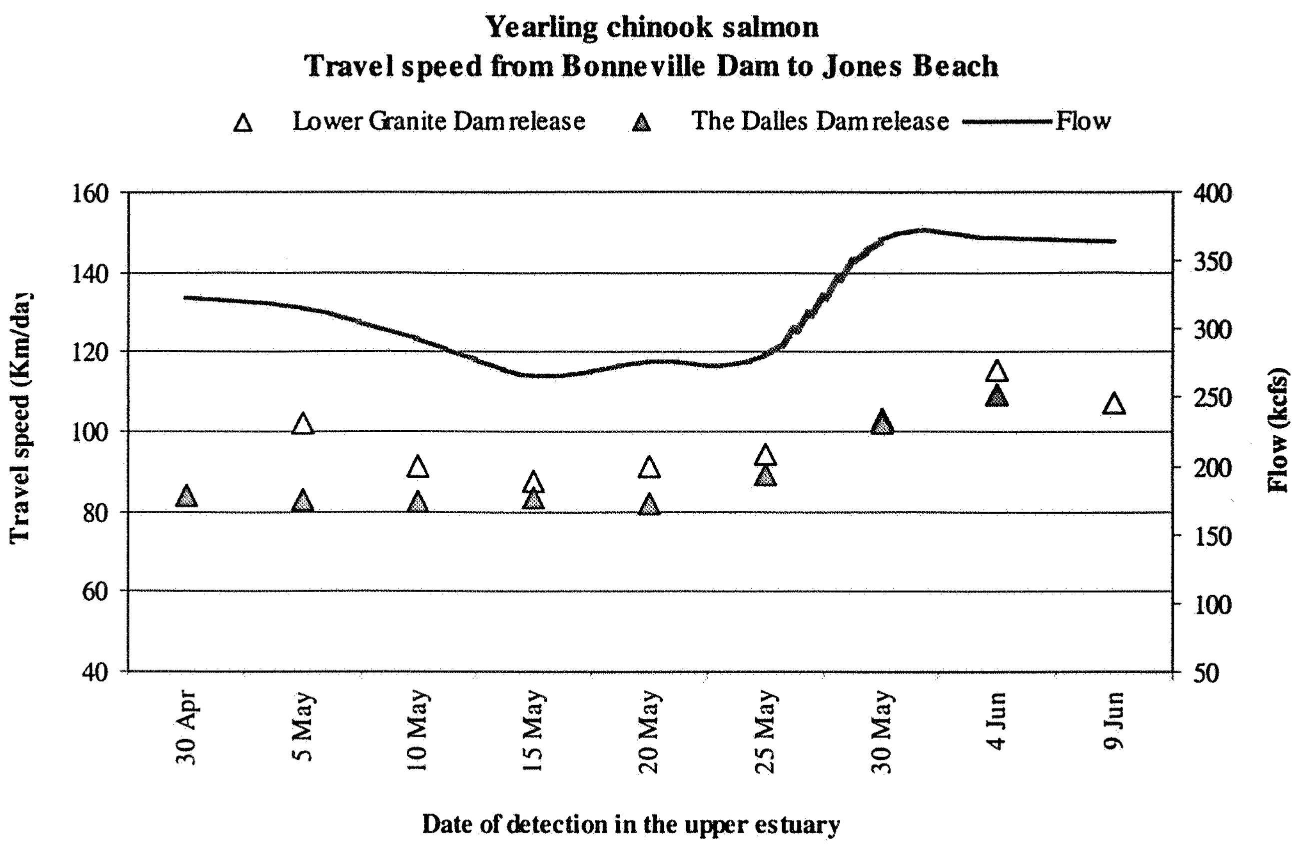


Figure 12. Mean travel speed (5 day averages) for yearling chinook salmon to the upper estuary at Jones Beach for fish detected at Bonneville Dam and released at Lower Granite Dam or The Dalles Dam, 1999.

Table 2. Coefficients of determination for various release groups of juvenile salmonids comparing fork length recorded at tagging to travel time (days) to the Columbia River estuary at Jones Beach, 1999.

Release site (PTAGIS code[a]), RKm	Days between tagging and release[b]	n	Coefficient of determination (R^2)
Yearling chinook			
Carson Hatchery (CARS), 279	101 to 104	63	0.167
Rapid River Hat. (RAPH), 978	50 to 65	500	0.011
Lower Monumental Dam (LMN[a]), 589	1 to 3	488	0.025
The Dalles Dam (TDA[a]), 308	1 to 3	252	0.004
Clearwater River (CLWRNF), 811	31 to 56	570	0.000
Knox Bridge (KNOXB), 1152	47 to 50	518	0.005
Lower Granite Dam (LGRRRR), 695	1 to 2	956	0.011
Steelhead			
Lower Granite Dam (LGRRRR), 695	1 to 2	920	0.014
Reservoir of Wells Dam (COLR), 841-860	1 to 2	344	0.012
Wells Dam (WEL[a]), 830	1 to 2	362	0.000
Okanagan River (OKANR), 858	1 to 2	128	0.008
Rock Island Dam (RIS), 730	1 to 2	534	0.106
Rocky Reach Dam (RRE), 763	1 to 2	443	0.126

a Release site with more than one PTAGIS code for various treatments which were pooled for our analysis.
b The range in days between tagging (when the fork lengths were recorded) and release date of the fish.

Table 3. Daily estuary detection rate of PIT-tagged juvenile salmonids previously detected in the bypass system at Bonneville Dam, 1999[a]

Bonneville Dam detections (all salmonids pooled)		Estuary detections (all salmonids pooled)		Estuary detection rate by salmonid species (% of Bonneville Dam daily detections)			
Date[b]	n	n	%	Yearling chinook	Coho	Steelhead	Sockeye
24 Apr	926	9	0.97	1.04	0	0	--[c]
25 Apr	905	7	0.77	0.72	0	2.63	--
26 Apr	501	5	1	1.21	0.00	0	--
27 Apr	510	3	0.59	0.00	0.00	2.19	--
28 Apr	605	15	2.48	1.86	11.76	3.81	--
29 Apr	698	11	1.58	1.79	0.00	1.14	--
30 Apr	255	5	1.96	2.73	0.00	0.00	--
1 May	1,278	22	1.72	1.63	0.00	2.82	0
2 May	1,235	11	0.89	0.82	1.48	0.82	0
3 May	1,353	30	2.22	1.96	2.89	2.56	0
4 May	1,495	13	0.87	0.97	0.64	0.72	0
5 May	1,389	19	1.37	1.35	2.15	0.98	100
6 May	1,759	16	0.91	0.74	0.63	1.34	0
7 May	2,550	37	1.45	1.82	0.00	1.38	0
8 May	2,224	46	2.07	1.72	2.79	2.31	0
9 May	2,213	64	2.89	2.57	3.03	3.58	0
10 May	3,137	113	3.6	3.27	2.53	4.64	0
11 May	2,899	69	2.38	2.15	1.38	3.14	0.00
12 May	2,523	49	1.94	1.77	1.35	2.19	0.00
13 May	2,077	66	3.18	2.70	4.49	3.59	8.33
14 May	2,820	73	2.59	2.19	2.58	3.36	0.00
15 May	2,899	73	2.52	2.21	1.92	3.41	0
16 May	2,846	64	2.25	1.85	1.11	3.19	7.14

Table 3. Continued.

Bonneville Dam detections (all salmonids pooled)		Estuary detections (all salmonids pooled)		Estuary detection rate by salmonid species (% of Bonneville Dam daily detections)			
Date[b]	n	n	%	Yearling chinook	Coho	Steelhead	Sockeye
17 May	2,597	95	3.66	2.99	0.00	5.13	16.67
18 May	2,460	64	2.60	2.53	0.00	2.79	0
19 May	3,534	78	2.21	2.04	0.71	2.88	0
20 May	3,946	58	1.47	1.64	0.00	1.15	12.50
21 May	4,856	103	2.12	2.41	2.81	1.08	14.29
22 May	3,069	136	4.43	4.26	3.88	4.80	8.33
23 May	2,897	66	2.28	2.28	2.88	2.23	0
24 May	2,912	36	1.24	1.15	1.64	1.26	7.14
25 May	3,815	96	2.52	2.54	1.18	2.79	0
26 May	2,937	32	1.09	1.21	0.00	0.95	0
27 May	2,950	29	0.98	1.06	0.68	0.80	0
28 May	2,860	41	1.43	1.51	1.82	1.09	0.00
29 May	2,038	65	3.19	2.98	2.83	3.81	0.00
30 May	1,987	22	1.11	1.07	0.49	1.29	16.67
31 May	2,852	114	4.00	3.93	1.70	4.50	0
1 Jun	2,539	116	4.57	4.83	0.00	4.69	9.09
2 Jun	1,991	43	2.16	2.58	5.00	1.61	6.67
Total or mean	89,336	1,985	2.22	2.08	1.69	2.61	4.29

a Data selected for intensive estuary sampling period allowing 2 days travel time from Bonneville Dam.
b Counts based on date at Bonneville Dam with a range of estuary detection dates percentages.
c Indicates dates when no fish of that species was detected at Bonneville Dam.

Survival Estimates for Inriver Migrant Fish

Estimated survival probabilities between McNary and Bonneville Dams were developed for PIT-tagged fish detected and returned to the tailrace of McNary Dam in 1999. Daily groups of Snake River yearling chinook salmon and steelhead and mid-Columbia River yearling chinook salmon and steelhead were pooled weekly; survival probabilities were estimated for the McNary to John Day, John Day to Bonneville, and McNary to Bonneville Dams reaches. For the entire reach, mean survival was highest for mid-Columbia River steelhead (74.2%; SE = 7.6) and lowest for mid-Columbia River yearling chinook salmon (57.0%; SE = 12.2).

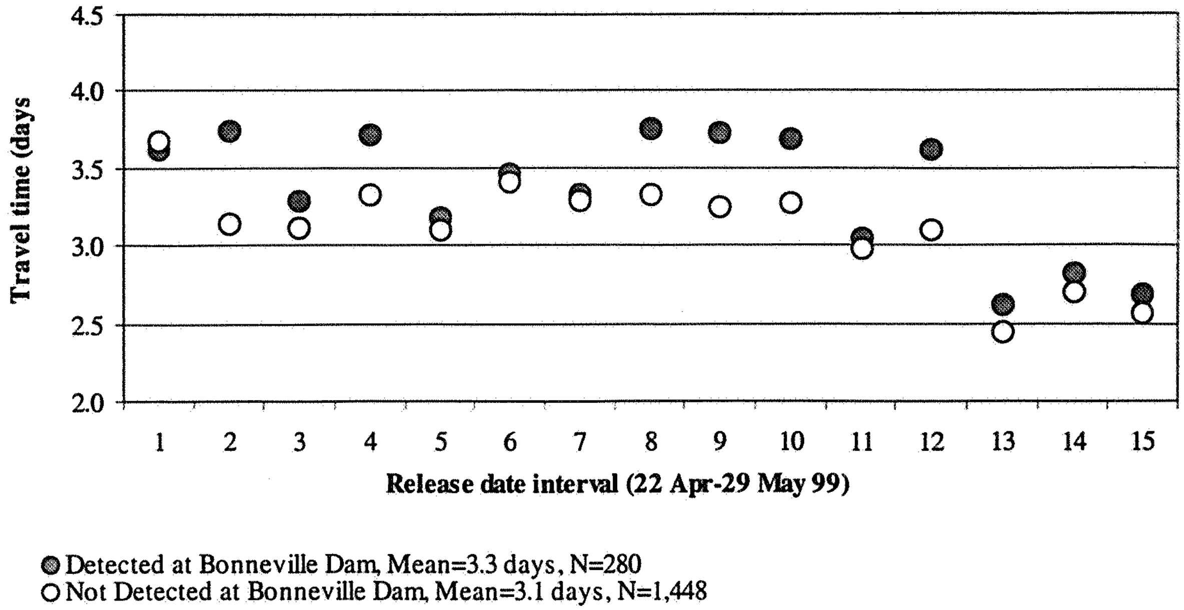
For all species, mean estimated survival probability was lower between John Day and Bonneville Dams than McNary and John Day Dams (Appendix Table 9). The seasonal average survival for inriver migrants from the tailrace of Lower Granite Dam to the tailrace of Bonneville Dam in 1999 was 53% (SE 4.9) for yearling chinook salmon and 48% (SE 2.9) for steelhead (Steve Smith, NMFS, Personal communication).

Delay of Fish Detected at Bonneville Dam

To examine the assumption that treatment and control groups used in the single-release mark-recapture model for estimating survival were adequately mixed downstream from Bonneville Dam, we analyzed travel time to Jones Beach for PIT-tagged fish released at The Dalles Dam and detected (control group) or not detected (treatment group) at Bonneville Dam (Figure 13). For yearling chinook salmon, fish not detected at the dam arrived at Jones Beach significantly earlier (mean difference 5.8 hours) than those previously detected at the dam (P <0.01). On average, coho salmon not detected at Bonneville Dam arrived at Jones Beach 4.4 hours earlier than those not detected, but the difference was not significant (P = 0.09).

The travel time difference for yearling chinook salmon appeared consistent through 15 paired comparisons; the mean travel times for previously detected fish were longer than for detected fish in every case but one. Data for coho salmon showed the same trend, where detected fish were slower than non-detected in seven of nine paired comparisons.

Travel time for detected vs. non-detected yearling chinook salmon
The Dalles Dam to Jones Beach, 1999



Travel time for detected vs. non-detected coho salmon
The Dalles Dam to Jones Beach, 1999

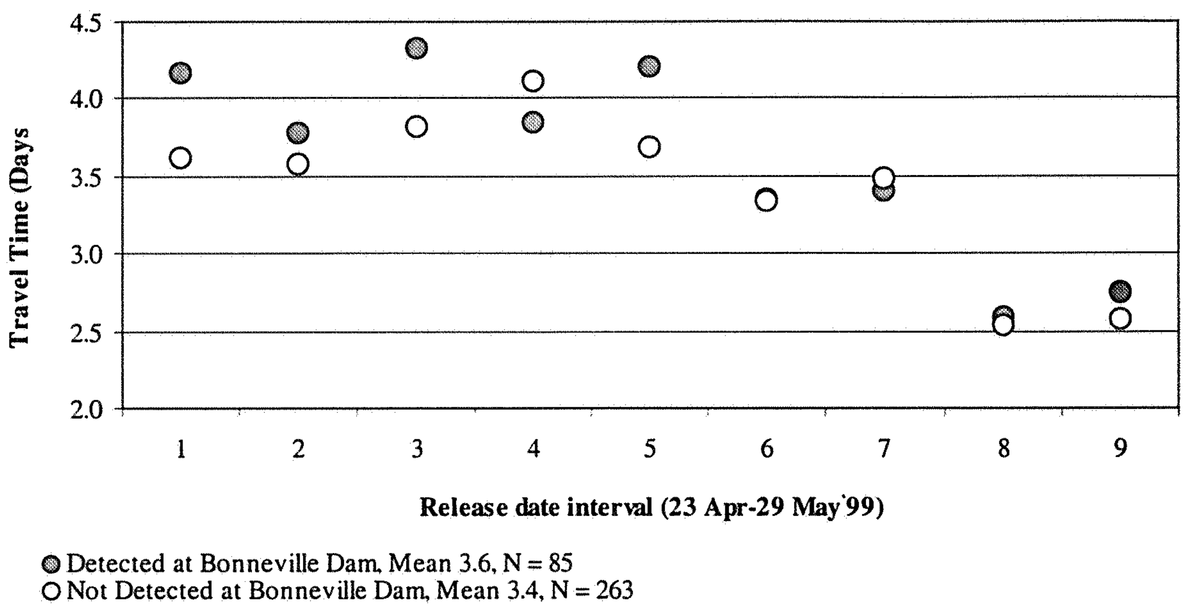


Figure 13. Travel time from release at The Dalles Dam to the estuary at Jones Beach for yearling chinook and coho salmon detected or not detected at Bonneville Dam, 1999. Data from adjacent release dates were combined until a minimum of 5 individuals were available in each group for the comparison.

DISCUSSION

Volitional fish passage through the enlarged detector opening used in 1999 was much improved over the 3-pipe system used in 1998. To avoid fatiguing fish reluctant to exit or fish thought to delay near the entrance of the trawl body, we continued to bring the wings of the net together to "flush" fish about every 15 minutes. While volitional passage increased, most detections occurred during the flushing procedure.

The new electronic system and trawl design, coupled with our existing vessels proved reliable and resulted in increased sampling effort and PIT-tag detections over previous years. The enlarged opening of the detector increased water flow, fish passage, and debris passage through the detector and out of the trawl body; however, the increased flow through the system also limited our ability to periodically collect an unbiased sample of fish exiting the system to evaluate descaling and potential injury.

Instead we relied on nearly continuous video observations and diver observations of the net to assess potential impacts to fish during passage through the system. Our observations led us to conclude that compared to previous designs, the enlarged opening had a significantly smaller buffer area of current in front of the detector, and fish exited the system swiftly and rarely came in contact with the net or detector.

Fish groups that are tagged and released together but that migrate at different speeds or arrive at the sample site with different distributions are subject to different conditions and sampling effort. Travel time distribution analyses were used to better define migration behavior and comparability of detection rates for fish groups released at different locations. For example, the longer period of availability in the estuary for fish released at Lower Granite Dam to migrate in river probably accounted for the greater number of detections of these fish than of transported fish.

During their 154-km migration from release below Bonneville Dam to the estuary at Jones Beach, fish released from barges apparently did not disperse widely, thus these fish passed our sampling site in a compact distribution. In contrast, the distribution of inriver migrants was protracted, as might be expected following the 620-km migration from Lower Granite Dam. Detection rates of barged fish were probably more affected by duration of the sampling period and time of daily sampling than those of the more broadly distributed inriver migrants.

We also noted differences in travel time distributions in the estuary among inriver migrant fish previously detected at Bonneville Dam compared to those released from barges, with barged fish available to the trawl sampling in the estuary slightly longer.

Among fish released from barges, hatchery yearling chinook salmon migrated to Jones Beach slowly relative to wild fish; however, both wild and hatchery steelhead migrated more quickly and were available for a shorter period than yearling chinook salmon.

Differences in estuarine distributions and timing were also noted among wild and hatchery fish released for inriver migration at Lower Granite Dam. At a minimum, these results suggest caution when pooling information among and between different groups of fish. For example, smolt-to-adult return rates could be affected by differences in estuarine distribution and timing within a major release group.

Transported fish groups arrived in the estuary and presumably entered the ocean several days to weeks prior to the associated inriver fish groups tagged on the same day and released into the tailrace of Lower Granite Dam. Ocean conditions and other factors, such as the degree of development to the smolt stage, often change rapidly and can affect survival, complicating smolt to adult return comparisons between fish groups with different ocean entrance timing. However, by sampling for PIT-tagged fish in the estuary, we were able to better define timing of the respective fish groups to the ocean, and this information should facilitate evaluation of subsequent adult returns.

We used PIT-tagged fish release information provided by the PTAGIS regional database in our analyses. While this database is carefully maintained and regularly updated by regional researchers, it should be used with caution. Comparisons between various release groups provided in this report were considered preliminary until confirmed with the agencies responsible for marking and releasing the specific fish groups because sub-grouping may have occurred that is not expressed in the PTAGIS release information. For example, fish groups released at The Dalles Dam included day and night release groups which were pooled in PTAGIS.

Also, we suspect that wild rearing type designation for individual fish in PTAGIS may have considerable error in certain instances where unclipped hatchery fish were designated wild in PTAGIS based on the presence of an adipose fin. We corrected the PTAGIS release date and kilometer of release for fish transported by barge from Lower Granite Dam in our database and used this to evaluate estuarine behavior of transported fish. This correction is a manual process; the data must be retrieved from records maintained for each barge by the U.S. Army Corps of Engineers and is not yet available to the PTAGIS database system (Appendix Table 1).

Without the ability to detect PIT-tagged fish below Bonneville Dam, accurate survival estimates for fish that pass this dam undetected are not possible. Survival estimates obtained from non-continuous sampling mechanisms could be affected by a lack of mixing. For fish released at The Dalles Dam, we found that individuals detected at Bonneville Dam arrived in the estuary several hours later than their cohorts that were not detected at Bonneville Dam.

Such a timing difference for fish in the same release group raises concern when using mark-recapture models to estimate survival. Estimates could be biased if there are different probabilities of detecting a fish for different components of the release group. The mobile PIT-tag detection system operated in a pair-trawl independent of hydroelectric facilities provided a unique opportunity to evaluate this assumption.

We believe that the mechanism for the observed difference in travel time to Jones Beach for fish released at The Dalles Dam was delay of fish passing Bonneville Dam through the powerhouse (detected group) compared to the non-detected group, of which the majority presumably passed through the spillway. Radio-tracking information for fish arriving in the forebay at Bonneville Dam during daylight shows little delay of fish passing via the spillway and up to several hours delay for those entering the powerhouse (H. Hansel, U.S. Geological Survey, Personal communication).

We made no attempt to filter the data by release timing for releases at The Dalles Dam (both day and night releases were made) that may have arrived in the forebay of Bonneville Dam during daylight. Fish arriving in the forebay during daylight would presumably have longer delay before entering the powerhouse than those arriving at dusk. Differences in travel time suggest that detected and non-detected fish downstream from Bonneville Dam may not mix adequately to avoid biased survival estimates when using mark-recapture models.

RECOMMENDATIONS

1) Releases of PIT-tagged fish in the Columbia River Basin after 1999 will utilize 134.2-kHz ISO systems, and we will adapt surface trawl electronics to detect these fish in future years. The switch to ISO equipment should provide larger diameter antenna openings (91-cm or more) and result in better fish passage through the trawl and detector and reduced debris accumulation.

2) Additional information on transportation barge or truck release time, location, and date should be recorded and be made available through the regional PTAGIS information database. The recording procedures should be standardized between dams and barges such that when coupled with date, time, and detection location (observation site at dam indicating diversion to transportation), researchers can determine which specific barge or truck a PIT-tagged fish was diverted into.

3) Additional validation of the mixing assumption required by the single-release model for estimating survival for inriver migrant fish should be attempted for other release groups and at more detection locations.

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APPENDICES

Appendix Table 1. Corrections to the PTAGIS release information for Snake River transportation study fish transported by barge from Lower Granite Dam and subsequently released downstream from Bonneville Dam, 1999.

Barge	Date and time of raceway loading at Lower Granite Dam[a]	Date and time of release below Bonneville Dam[b]	Barge release site (Columbia RKm)
NA[c]	31 Mar 10:00	1 Apr 22:00	225
8105	8 Apr 10:00	9 Apr 21:00	222
8106	10 Apr 10:00	11 Apr 18:02	224
8107	12 Apr 10:00	13 Apr 18:10	225
8108	14 Apr 10:00	15 Apr 17:10	225
8107	16 Apr 10:00	17 Apr 19:45	225
4382	18 Apr 10:00	19 Apr 19:15	222
8107	20 Apr 10:00	21 Apr 20:15	224
8108	22 Apr 10:00	23 Apr 23:00	225
8105	23 Apr 10:00	25 Apr 00:20	225
8106	24 Apr 10:00	26 Apr 00:03	222
8107	25 Apr 10:00	26 Apr 20:40	227
8108	26 Apr 10:00	27 Apr 22:30	225
8105	27 Apr 10:00	28 Apr 21:35	225
8106	28 Apr 10:00	29 Apr 22:30	222
8107	29 Apr 10:00	30 Apr 18:55	227
8108	30 Apr 10:00	1 May 21:50	225
8105	1 May 10:00	2 May 23:40	225
8106	2 May 10:00	3 May 22:51	222
8107	3 May 10:00	4 May 21:15	227
8108	4 May 10:00	6 May 01:30	225
8105	5 May 10:00	6 May 23:45	225
8106	6 May 10:00	7 May 19:00	222
8107	7 May 10:00	8 May 19:50	227
8108	8 May 10:00	9 May 22:28	225
8105	9 May 10:00	10 May 20:40	225
8106	NA	11 May 19:55	222
8107	11 May 10:00	12 May 20:35	227
8108	12 May 10:00	13 May 21:55	225
8105	13 May 10:00	14 May 21:15	225
8106	14 May 10:00	15 May 19:15	222
8107	15 May 10:00	16 May 19:40	227
8108	NA	18 May 07:30	225

Appendix Table 1. Continued.

Barge	Date and time of raceway loading at Lower Granite Dam[a]	Date and time of release below Bonneville Dam[b]	Barge release site (Columbia RKm)
8105	NA	18 May 18:20	225
8106	18 May 10:00	19 May 19:55	222
8107	19 May 10:00	20 May 19:15	227
8108	20 May 10:00	21 May 17:55	225
8105	21 May 10:00	22 May 19:30	225
8106	22 May 10:00	23 May 20:30	222
8107	NA	24 May 21:45	227
8108	NA	25 May 21:50	225
8106	26 May 10:00	27 May 17:20	222
8107	27 May 10:00	28 May 20:50	227
8108	NA	29 May 18:05	225
8105	NA	31 May 20:00	220
8107	NA	1 Jun 17:10	225
8108	NA	2 Jun 19:10	225
8106	NA	4 Jun 18:10	222
NA	4 Jun 10:00	NA	NA
8108	5 Jun 10:00	6 Jun 22:03	225
8105	7 Jun 10:00	8 Jun 22:00	225
8108	9 Jun 10:00	10 Jun 18:05	225
8107	11 Jun 10:00	12 Jun 16:20	227
8108	NA	14 Jun 15:40	227
NA	14 Jun 10:00	NA	NA
8107	15 Jun 10:00	16 Jun 16:15	222
8108	17 Jun 10:00	18 Jun 17:45	227
8107	19 Jun 10:00	20 Jun 15:50	225
8108	21 Jun 10:00	22 Jun 17:35	225
8107	23 Jun 10:00	25 Jun 03:15	220
8108	NA	27 Jun 05:15	225

a Raceway loading data downloaded from the PTAGIS regional database.

b Barge release data were obtained from the USACE (Michael Halter and Dave Hurson, USACE, Lower Granite Dam, Personal communication) and compared with data from PITAGIS to verify release information for all PIT-tagged fish with release site code LGRRBR.

c NA = Data not available.

Appendix Table 2. Daily total PIT-tag detections for each salmonid species using a surface trawl on the Columbia River estuary at Jones Beach, 1999.

Detection date	Unknown	Yearling chinook	Coho	Steelhead	Sockeye	Total
Apr 13				1		1
Apr 15		1				1
Apr 21		1				2
Apr 22	1	1				2
Apr 23				1		2
Apr 26	2	46	4	17		69
Apr 27	3	58	2	18		81
Apr 28		18		24		42
Apr 29		21		24		45
Apr 30	3	135	7	31		176
May 1	3	103	6	32		144
May 2	2	122	2	77		203
May 3	2	84	4	30		120
May 4	1	91	8	31		131
May 5	5	163	14	73		255
May 6		45	5	20		70
May 7	2	66	3	41	1	113
May 8		67	4	27	1	99
May 9	1	187	20	87		295
May 10	7	180	30	62		279
May 11	11	261	23	144		439
May 12	3	291	22	201		517
May 13	8	277	25	97	2	409
May 14		102	5	111	1	219
May 15	6	171	7	140	4	328
May 16	6	255	20	132	5	418
May 17	8	292	7	157	1	465
May 18	4	172	8	113	3	300

Appendix Table 2. Continued.

Detection date	Unknown	Yearling chinook	Coho	Steelhead	Sockeye	Total
May 19	2	314	4	246	1	567
May 20	7	242	3	124	4	380
May 21	5	164	6	115	2	292
May 22	3	294	8	112	4	421
May 23	4	543	25	289	5	866
May 24	4	289	16	238	5	552
May 25	1	145	8	151		305
May 26	4	244	8	146	5	407
May 27	2	234	14	35	3	288
May 28	5	222	3	57	2	289
May 30	3	216	26	111	4	360
May 31	4	177	2	40	4	227
Jun 1	4	332	25	123	2	486
Jun 2	5	290	18	197	4	514
Jun 3	7	222	4	189	6	428
Jun 4	5	115	14	107	4	245
Jun 5	1	52	7	68	1	129
Jun 6	1	36	1	35	1	74
Jun 7	1	20	3	26	3	53
Jun 8		12		12		24
Totals	146	7,373	421	4,114	78	12,132

Appendix Table 3. Number of descaled, injured, and dead juvenile salmon identified by species that were recovered in a sanctuary bag sample net attached to the cod end of the surface trawl detection system, 1999. Numbers include fish observed by divers trapped in the trawl and numbers seen upon retrieval of the net. n, sample size; D, descaled; M, mortalities; and I, injuries. Totals are shown in Appendix Table 4.

	Spring /summer chinook salmon				Fall chinook salmon				Coho salmon				Steelhead				Sockeye salmon			
Date	n	D	M	I	n	D	M	I	n	D	M	I	n	D	M	I	n	D	M	I
22 Apr*	18	1	0	0	0	0	0	0	3	0	0	0	8	0	1	0	0	0	0	0
23 Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24 Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25 Apr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26 Apr	0	0	0	0	4	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
27 Apr	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
28 Apr	0	0	0	0	16	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0
29 Apr*	24	6	0	0	7	0	0	0	7	1	0	0	84	2	0	0	0	0	0	0
30 Apr	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 May *	22	5	3	0	4	0	0	0	4	0	0	0	40	0	0	0	2	1	0	0
7 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 May	3	0	3	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
9 May	0	0	0	0	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0
10 May	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0
11 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0
12 May	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0
13 May	7	0	7	0	0	0	0	0	3	0	3	0	0	0	0	0	10	0	10	0
14 May *	45	3	0	0	7	1	0	0	20	2	0	0	62	1	1	1	64	33	0	0
15 May	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	8	0	8	0
16 May	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17 May	0	0	0	0	3	0	3	0	0	0	0	0	0	0	0	0	6	0	6	0
18 May	2	0	2	0	8	0	8	0	0	0	0	0	0	0	0	0	1	0	1	0
19 May	5	0	5	0	1	0	1	0	0	0	0	0	1	0	1	0	9	0	9	0
20 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21 May	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22 May	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
23 May	1	0	1	0	1	0	1	0	1	0	1	0	0	0	0	0	21	0	21	0

Appendix Table 3. Continued.

Date	Spring /summer chinook salmon n	D	M	I	Fall chinook salmon n	D	M	I	Coho salmon n	D	M	I	Steelhead n	D	M	I	Sockeye salmon n	D	M	I
24 May	1	0	1	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
25 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26 May	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
27 May	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
28 May	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
29 May	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0
30 May	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31 May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1 Jun	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
2 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8 Jun	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
9 Jun	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	133	15	27	0	65	1	47	0	46	3	12	0	198	3	6	1	127	34	61	0

Appendix Table 4. Fish that could not be accurately identified by the divers or during net retrieval. All fish observed in this manner were counted as mortalities. Species proportions were based on our 1998 observation of species composition in the sanctuary bag collection net: 30 % spring/summer (yearling) chinook salmon; 10% fall (subyearling) chinook salmon; 20% coho salmon; 31 % steelhead; and 9 % sockeye salmon.

	Species breakdown of unidentified salmonids						Total salmonids			
Date	n	Yearling chinook	Subyearling chinook	Coho	Steelhead	Sockeye	n	Descaled	Dead	Injured
22 Apr	2	0	0	1	0	0	31	1	3	0
23 Apr	0	0	0	0	0	0	0	0	0	0
24 Apr	0	0	0	0	0	0	0	0	0	0
25 Apr	0	0	0	0	0	0	0	0	0	0
26 Apr	1	0	0	0	0	0	5	0	5	0
27 Apr	0	0	0	0	0	0	1	0	1	0
28 Apr	48	11	10	14	11	1	64	0	64	0
29 Apr	3	1	1	1	1	0	125	9	3	0
30 Apr	0	0	0	0	0	0	1	0	1	0
1 May	52	12	11	16	12	2	52	0	52	0
2 May	1	0	0	0	0	0	1	0	1	0
3 May	0	0	0	0	0	0	0	0	0	0
4 May	7	2	1	2	2	0	7	0	7	0
5 May	7	2	1	2	2	0	7	0	7	0
6 May	16	4	3	5	4	0	88	6	19	0
7 May	12	3	3	4	3	0	12	0	12	0
8 May	13	3	3	4	3	0	17	0	17	0
9 May	2	0	0	1	0	0	5	0	5	0
10 May	1	0	0	0	0	0	3	0	3	0
11 May	1	0	0	0	0	0	3	0	3	0
12 May	38	9	8	11	9	1	42	0	42	0
13 May	1	0	0	0	0	0	21	0	21	0
14 May	9	2	2	3	2	0	207	40	10	1
15 May	23	5	5	7	5	1	34	0	34	0
16 May	34	8	7	10	8	1	35	0	35	0
17 May	14	3	3	4	3	0	23	0	23	0
18 May	10	2	2	3	2	0	21	0	21	0
19 May	144	33	30	43	33	4	160	0	160	0
20 May	17	4	4	5	4	1	17	0	17	0
21 May	2	0	0	1	0	0	3	0	3	0
22 May	18	4	4	5	4	1	19	0	19	0
23 May	12	3	3	4	3	0	36	0	36	0

Appendix Table 4. Continued.

Date	Species breakdown of unidentified salmonids: n	Yearling chinook	Subyearling chinook	Coho	Steelhead	Sockeye	Total salmonids: n	Descaled	Dead	Injured
24 May	15	3	3	5	3	0	18	0	18	0
25 May	2	0	0	1	0	0	2	0	2	0
26 May	30	7	6	9	7	1	32	0	32	0
27 May	6	1	1	2	1	0	8	0	8	0
28 May	2	0	0	1	0	0	4	0	4	0
29 May	0	0	0	0	0	0	2	0	2	0
30 May	1	0	0	0	0	0	2	0	2	0
31 May	4	1	1	1	1	0	4	0	4	0
1 Jun	6	1	1	2	1	0	7	0	7	0
2 Jun	1	0	0	0	0	0	1	0	1	0
3 Jun	1	0	0	0	0	0	1	0	1	0
4 Jun	3	1	1	1	1	0	3	0	3	0
5 Jun	0	0	0	0	0	0	0	0	0	0
6 Jun	1	0	0	0	0	0	1	0	1	0
7 Jun	0	0	0	0	0	0	0	0	0	0
8 Jun	1	0	0	0	0	0	2	0	2	0
9 Jun	0	0	0	0	0	0	0	0	0	0
Totals	**561**	**129**	**118**	**168**	**129**	**17**	**1127**	**56**	**710**	**1**

Appendix Table 5. Diel sampling of juvenile spring/summer chinook salmon using a PIT-tag detector/trawl in the upper estuary at Jones Beach, Columbia River Kilometer 75, 1999.

Yearling chinook diel period 1: 12-13 May				Yearling chinook diel period 2: 19-20 May			
Hour	Effort (decimal hour)	n	n/hour	Hour	Effort (decimal hour)	n	n/hour
0	0.95	20	21.05	0	0.00	0	0.00
1	1.00	8	8.00	1	0.38	2	5.22
2	0.88	36	40.75	2	1.00	12	12.00
3	1.00	33	33.00	3	0.93	7	7.50
4	0.85	10	11.76	4	1.00	7	7.00
5	1.17	17	14.57	5	1.00	10	10.00
6	1.68	95	56.44	6	1.52	44	29.01
7	2.00	25	12.50	7	2.00	44	22.00
8	1.68	28	16.63	8	2.00	23	11.50
9	1.80	5	2.78	9	1.47	35	23.86
10	2.00	31	15.50	10	2.00	24	12.00
11	2.00	19	9.50	11	1.78	21	11.78
12	0.97	22	22.76	12	0.97	21	21.72
13	1.00	12	12.00	13	1.00	15	15.00
14	0.90	8	8.89	14	1.00	31	31.00
15	0.97	8	8.28	15	0.88	29	32.83
16	1.53	21	13.70	16	1.00	23	23.00
17	1.97	16	8.14	17	1.43	19	13.26
18	1.72	21	12.23	18	1.63	14	8.57
19	1.95	19	9.74	19	1.92	27	14.09
20	0.95	1	1.05	20	1.97	46	23.39
21	1.77	53	30.00	21	1.82	55	30.28
22	1.17	20	17.14	22	1.30	20	15.38
23	0.88	10	11.32	23	0.02	0	0.00

Appendix Table 5. Continued.

Yearling chinook diel period 3: 26-27 May				Yearling chinook all diel periods			
Hour	Effort (decimal hour)	n	n/hour	Hour	Effort (decimal hour)	n	n/hour
0	0.93	33	35.36	0	1.88	53	28.1
1	1	32	32	1	2.38	42	17.6
2	0.9	40	44.44	2	2.78	88	31.6
3	0.77	38	49.57	3	2.7	78	28.9
4	0	-	-	4	1.85	17	9.2
5	0	-	-	5	2.17	27	12.5
6	0.3	2	6.67	6	3.5	141	40.3
7	1.4	20	14.29	7	5.4	89	16.5
8	1.83	34	18.55	8	5.52	85	15.4
9	1.92	36	18.78	9	5.18	76	14.7
10	1.78	37	20.75	10	5.78	92	15.9
11	1	8	8	11	4.78	48	10
12	0.92	10	10.91	12	2.85	53	18.6
13	1	17	17	13	3	44	14.7
14	1	18	18	14	2.9	57	19.7
15	1	19	19	15	2.85	56	19.6
16	0.77	8	10.43	16	3.3	52	15.8
17	0.43	3	6.92	17	3.83	38	9.9
18	0.33	0	0	18	3.68	35	9.5
19	1	8	8	19	4.87	54	11.1
20	1	26	26	20	3.92	73	18.6
21	0.95	45	47.37	21	4.53	153	33.8
22	0.95	21	22.11	22	3.42	61	17.9
23	1	16	16	23	1.9	26	13.7

Appendix Table 6. Diel sampling of juvenile steelhead using a PIT-tag detector/trawl in the upper estuary at Jones Beach, Columbia River Kilometer 75, 1999.

Steelhead diel period 1: 12-13 May				Steelhead diel period 2: 19-20 May			
Hour	Effort (decimal hour)	n	n/hour	Hour	Effort (decimal hour)	n	n/hour
0	0.95	3	3.2	0	0.00	-	-
1	1.00	2	2.0	1	0.38	0	0.0
2	0.88	4	4.5	2	1.00	1	1.0
3	1.00	5	5.0	3	0.93	1	1.1
4	0.85	1	1.2	4	1.00	0	0.0
5	1.17	3	2.6	5	1.00	0	0.0
6	1.68	25	14.9	6	1.52	11	7.3
7	2.00	19	9.5	7	2.00	16	8.0
8	1.68	16	9.5	8	2.00	11	5.5
9	1.80	9	5.0	9	1.47	29	19.8
10	2.00	28	14.0	10	2.00	48	24.0
11	2.00	18	9.0	11	1.78	52	29.2
12	0.97	24	24.8	12	0.97	16	16.6
13	1.00	18	18.0	13	1.00	35	35.0
14	0.90	14	15.6	14	1.00	28	28.0
15	0.97	11	11.4	15	0.88	25	28.3
16	1.53	25	16.3	16	1.00	27	27.0
17	1.97	14	7.1	17	1.43	14	9.8
18	1.72	26	15.2	18	1.63	10	6.1
19	1.95	13	6.7	19	1.92	17	8.9
20	0.95	5	5.3	20	1.97	10	5.1
21	1.77	8	4.5	21	1.82	14	7.7
22	1.17	7	6.0	22	1.30	4	3.1
23	0.88	0	0.0	23	0.02	0	0.0

Appendix Table 6.

Steelhead diel period 3: 26-27 May				Steelhead all diel periods			
Hour	Effort (decimal hour)	n	n/hour	Hour	Effort (decimal hour)	n	n/hour
0	0.93	9	9.6	0	1.88	12	6.4
1	1.00	9	9.0	1	2.38	11	4.6
2	0.90	2	2.2	2	2.78	7	2.5
3	0.77	7	9.1	3	2.70	13	4.8
4	0.00	0	-	4	1.85	1	0.5
5	0.00	0	-	5	2.17	3	1.4
6	0.30	0	0.0	6	3.50	36	10.3
7	1.40	0	0.0	7	5.40	35	6.5
8	1.83	1	0.6	8	5.52	28	5.1
9	1.92	5	2.6	9	5.18	43	8.3
10	1.78	9	5.1	10	5.78	85	14.7
11	1.00	14	14.0	11	4.78	84	17.6
12	0.92	10	10.9	12	2.85	50	17.5
13	1.00	15	15.0	13	3.00	68	22.7
14	1.00	12	12.0	14	2.90	54	18.6
15	1.00	9	9.0	15	2.85	45	15.8
16	0.77	4	5.2	16	3.30	56	17.0
17	0.43	0	0.0	17	3.83	28	7.3
18	0.33	0	0.0	18	3.68	36	9.8
19	1.00	8	8.0	19	4.87	38	7.8
20	1.00	23	23.0	20	3.92	38	9.7
21	0.95	24	25.3	21	4.53	46	10.1
22	0.95	12	12.6	22	3.42	23	6.7
23	1.00	7	7.0	23	1.90	7	3.7

Appendix Table 7. Estuary detection rates at Jones Beach for PIT-tagged wild and hatchery[a] yearling chinook salmon and steelhead released at Lower Granite Dam for inriver migration or transported and released downstream from Bonneville Dam, 1999.

Part A. Inriver migrant yearling chinook salmon

	Hatchery			Wild		
		Detection			Detection	
Date	Release	n	(%)[b]	Release	n	%[b]
18 Apr	270	4		109	2	
20 Apr	649	6		229	0	
21 Apr	1260	19	1.33	760	13	1.37
22 Apr	1489	17	1.14	679	8	1.18
23 Apr	2407	19	0.79	608	6	0.99
24 Apr	2041	27		549	4	
25 Apr	2167	27	1.28	370	4	0.87
26 Apr	1618	24		468	4	
27 Apr	2742	40	1.47	521	7	1.11
28 Apr	4505	45	1.00	936	18	1.92
29 Apr	3773	42	1.11	761	17	2.23
30 Apr	2,333	23	0.99	475	6	1.26
1 May	3170	45		462	4	
2 May	1802	31	1.53	303	9	1.7
3 May	3258	55	1.69	474	7	1.48
4 May	3110	39	1.25	421	11	2.61
5 May	5081	67	1.32	652	11	1.69
6 May	2,515	33		218	3	
7 May	1,172	19		109	1	
8 May	2,347	50	1.69	222	4	1.46
9 May	2,642	35		204	2	
11 May	1,486	17		123	1	
12 May	669	4		98	0	
13 May	879	10		41	0	
14 May	1,306	13		80	1	
15 May	836	6		30	0	
18 May	1,407	21	1.15	56	1	0.79
19 May	733	10		40	2	
20 May	609	9		52	0	
21 May	357	7		19	0	
22 May	362	12		29	1	
25 May	278	5		48	3	
26 May	435	9	1.87	65	2	3.16
Total/mean	59,708	790	1.31	10,211	152	1.59

Appendix Table 7. Continued.

Part B. Inriver migrant steelhead

Date	Hatchery			Wild		
		Detection			Detection	
	Release	n	%[b]	Release	n	%[b]
11 Apr	260	1		42	1	
13 Apr	123	2		10		
14 Apr	97			9	1	
15 Apr	305	5		26		
16 Apr	230	2		15		
17 Apr	1,452	32	1.70	298	6	2.00
18 Apr	582	10		44		
20 Apr	649	9		67	1	
21 Apr	372	2		86		
22 Apr	28	1		12	1	
23 Apr	996	23	1.71	471	5	1.03
24 Apr	1,193	16	1.34	599	10	1.67
25 Apr	2,078	36	1.73	946	17	1.80
27 Apr	1,399	16	1.14	324	8	2.47
28 Apr	1,863	32	1.72	340	6	1.76
29 Apr	1,673	37		289	4	
30 Apr	1,349	33	2.32	197	5	1.85
1 May	1,842	22	1.19	263	5	1.90
2 May	1,474	21		183	1	
3 May	1,176	20		145	3	
4 May	1,589	32	1.72	95	3	1.65
5 May	1,923	35		158	4	
6 May	3,715	63	1.74	246	5	2.23
7 May	1,729	30		131	3	
8 May	2,290	31	1.52	157	2	1.74
9 May	1,337	15		98	2	
11 May	2,343	22		119		
12 May	1,538	13		126	1	
13 May	1,485	18		109		
14 May	1,916	25		183	1	
15 May	2,316	24	1.07	183	5	1.10
17 May	1,018	5		136	2	
18 May	2,673	25		192	2	
19 May	1,524	22	1.00	144	4	1.69
20 May	1,713	21		158	4	
21 May	1,738	21	1.22	155	4	2.56
22 May	2,118	25	1.18	199	5	2.51
25 May	1,422	18	1.27	285	11	3.86
26 May	721	3		147	3	
27 May	2,596	10	0.39	318	5	1.72
Total/mean	56,845	778	1.41	7,705	140	1.97

Appendix Table 7. Continued.

Part C. Barged yearling chinook salmon

Transportation dates		Hatchery			Wild		
			Detection			Detection	
Lower Granite Dam, barge load date\time	Bonneville Dam barge release date\time	Release	n	(%)[b]	Release	n	(%)[b]
22 Apr 10:00	23 Apr 23:00	1,253	3		442	1	
23 Apr 10:00	25 Apr 00:20	1,463	11	0.52	445	4	0.56
24 Apr 10:00	26 Apr 00:03	1,158	6		396	3	
25 Apr 10:00	26 Apr 20:40	1,506	12	0.68	416	5	0.99
26 Apr 10:00	27 Apr 22:30	898	9	1.00	393	7	1.78
27 Apr 10:00	28 Apr 21:35	1,962	14	0.71	640	11	1.72
28 Apr 10:00	29 Apr 22:30	2,844	38	1.34	892	19	2.13
29 Apr 10:00	30 Apr 18:55	2,526	24	0.95	587	9	1.53
30 Apr 10:00	1 May 21:50	1,821	7		442	3	
1 May 10:00	2 May 23:40	1,699	8	0.43	249	3	0.87
2 May 10:00	3 May 22:51	1213	10		213	2	
3 May 10:00	4 May 21:15	1,571	11		202	1	
4 May 10:00	6 May 01:30	2854	17		376	1	
5 May 10:00	6 May 23:45	2,771	35	0.87	251	4	0.77
6 May 10:00	7 May 19:00	2,664	39		160	2	
7 May 10:00	8 May 19:50	1,179	16		90	0	
8 May 10:00	9 May 22:28	1,639	20		115	0	
9 May 10:00	10 May 20:40	1,886	37	1.52	161	4	1.14
11 May 10:00	12 May 20:35	1,307	9		129	3	
12 May 10:00	13 May 21:55	623	7		48	0	
13 May 10:00	14 May 21:15	798	7		41	0	
14 May 10:00	15 May 19:15	903	9		40	1	
15 May 10:00	16 May 19:40	633	3		29	1	
18 May 10:00	19 May 19:55	1,353	2		45	1	
19 May 10:00	20 May 19:15	573	4		40	1	
20 May 10:00	21 May 17:55	379	8		25	1	
21 May 10:00	22 May 19:30	292	6	0.8	15	0	1.94
Total/mean		39,768	372	0.88	6,882	87	1.34

Appendix Table 7. Continued.

Part D. Barged steelhead

Transportation dates		Hatchery			Wild		
			Detection			Detection	
Lower Granite Dam, barge load date\time	Bonneville Dam barge release date\time	Release	n	(%)[b]	Release	n	(%)[b]
23 Apr 10:00	25 Apr 00:20	809	7	0.87	334	8	2.4
24 Apr 10:00	26 Apr 00:03	681	10	1.47	323	5	1.55
25 Apr 10:00	26 Apr 20:40	1,333	24	1.80	627	9	1.44
26 Apr 10:00	27 Apr 22:30	12			6		
27 Apr 10:00	28 Apr 21:35	935	23		221	4	
28 Apr 10:00	29 Apr 22:30	1,475	23	1.90	205	3	1.62
29 Apr 10:00	30 Apr 18:55	1,172	45	3.84	182	8	4.4
30 Apr 10:00	1 May 21:50	1,131	6		174	1	
1 May 10:00	2 May 23:40	1,443	10		206		
2 May 10:00	3 May 22:51	1,414	19		123		
3 May 10:00	4 May 21:15	1,074	7		122		
4 May 10:00	6 May 01:30	1,284	14		64	3	
5 May 10:00	6 May 23:45	1,795	11	0.82	132	1	0.61
6 May 10:00	7 May 19:00	1,784	36		123	2	
7 May 10:00	8 May 19:50	1,036	14		63	2	
8 May 10:00	9 May 22:28	1,775	41	1.98	147	7	3.30
9 May 10:00	10 May 20:40	835	23		91	1	
11 May 10:00	12 May 20:35	1,405	19		90	2	
12 May 10:00	13 May 21:55	1,044	11	1.61	89	5	2.96
13 May 10:00	14 May 21:15	942	17		82	1	
14 May 10:00	15 May 19:15	1,273	21		124	2	
15 May 10:00	16 May 19:40	1,486	15	1.43	117	3	1.86
18 May 10:00	19 May 19:55	1,548	44	2.84	125	8	6.40
19 May 10:00	20 May 19:15	1,199	22		133	4	
20 May 10:00	21 May 17:55	1,274	57	3.19	139	8	4.41
21 May 10:00	22 May 19:30	1,241	46		122	4	
22 May 10:00	23 May 20:30	1,286	41		117	2	
26 May 10:00	27 May 17:20	2,343			550		
27 May 10:00	28 May 20:50	1,547	17	1.62	293	3	0.83
Total/mean		36,576	623	1.95	5,124	96	2.65

a. Rearing type recorded at the time of PIT-tagging at Lower Granite Dam based on the presence (wild) or absence (hatchery) of the adipose fin.

b. Detection percentages calculated by adding release and detection numbers for consecutive dates until we obtained a minimum of 5 detections for each hatchery and wild rearing type within the date range; these pairings were also utilized in the statistical analyses and reflect a subset of the total releases based on time period of pair trawl sampling.

Appendix Table 8. Analyses of travel time distributions for juvenile salmonids detected in the Columbia River estuary during 1999. Distributions of the 10th-90th and middle 80th percentile passage time (in days) were compared by species, rearing type, and migration history. Standard errors (SE) were constructed using bootstrap techniques (Efron and Tibshirani 1993). Differences were compared using *t*-tests with $\alpha = 0.05$.

Species/ Rearing type/ Migration history	n	Bootstrap analysis of the Comparison	Travel time distribution by percentiles 10	20	30	40	50	60	70	80	90	mid 80
Inriver migrants												
1) Hatchery yearling chinook vs. wild yearling chinook												
Hatchery	791	Travel time	12	14	14.6	15.46	16.1	16.99	17.85	18.97	21	9
Wild	168	Travel time	13	15	15.64	16.56	17.2	17.96	19	20.5	24.6	11.5
		Difference	-1	-1	-1.04	-1.1	-1.1	-0.97	-1.15	-1.53	-3.6	-2.5
		Lower	-2.6	-1.9	-1.6	-1.8	-1.7	-1.9	-2.4	-3.4	-6.4	-6.2
		Upper	1.8	-0.4	-0.5	-0.5	-0.7	-0.4	-0.2	-0.4	-0.9	0.5
Inriver migrants												
2) Hatchery steelhead vs. wild steelhead												
Hatchery	784	Travel time	11	13	14.15	15.15	16.44	17.49	19.07	20.57	24.3	12.9
Wild	140	Travel time	9.1	11	11.98	12.99	13.42	14.11	15.55	17.08	18.3	9.26
		Difference	2.4	2.6	2.17	2.16	3.025	3.38	3.52	3.49	6.03	3.67
		Lower	1.4	1.9	1.5	1.9	2.2	2.3	2.3	2.2	3.1	0.4
		Upper	3.6	3.7	3.3	3.3	3.9	4.2	4.7	5.1	7.1	4.9
Inriver migrants												
3) Hatchery yearling chinook vs. hatchery steelhead												
Yearling chinook	791	Difference	0.6	0.8	0.5	0.3	-0.34	-0.51	-1.18	-1.79	-3.4	-3.9
Steelhead	784	Lower	-0.6	0.4	0.2	-0.3	-1.0	-1.2	-1.7	-2.8	-4.6	-5.3
		Upper	1.4	1.0	1.0	0.5	0.1	-0.1	-0.4	-1.1	-2.0	-2.3
Inriver migrants												
4) Wild yearling chinook vs. wild steelhead												
Yearling chinook	168	Difference	4.1	4.4	3.98	3.72	3.835	3.79	3.37	3.82	5.68	1.84
Steelhead	140	Lower	1.1	3.3	3.0	2.9	3.0	2.5	2.2	2.0	2.4	-1.6
		Upper	5.7	5.7	5.1	4.9	4.5	4.8	5.0	5.9	8.4	5.5

Appendix Table 8. Continued.

Species/ Rearing type/ Migration history	n	Bootstrap analysis of the Comparison	Travel time distribution by percentiles 10	20	30	40	50	60	70	80	90	mid 80
Inriver migrants detected at Bonneville Dam												
5) Hatchery yearling chinook vs. wild yearling chinook												
Hatchery	167	Travel time	1.5	1.6	1.62	1.67	1.72	1.74	1.77	1.81	1.9	0.4
Wild	39	Travel time	1.5	1.6	1.64	1.72	1.76	1.79	1.82	1.88	1.9	0.37
		Difference	0	0	0	-0.1	0	-0.1	-0.1	-0.1	0	0
		Lower	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.3
		Upper	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2
Transported fish												
6) Hatchery yearling chinook vs. wild yearling chinook												
Hatchery	374	Travel time	1.9	2.1	2.29	2.38	2.475	2.6	2.87	3.25	3.82	1.92
Wild	88	Travel time	1.8	1.9	2.05	2.38	2.445	2.52	2.59	2.72	2.93	1.12
		Difference	0	0.2	0.24	0	0.03	0.08	0.28	0.53	0.89	0.8
		Lower	0.0	0.0	-0.1	-0.1	-0.1	0.0	0.1	0.2	0.3	0.2
		Upper	0.2	0.2	0.4	0.3	0.1	0.2	0.4	0.8	1.3	1.3
Hatchery yearling chinook salmon												
7) Inriver migrants detected at Bonneville Dam vs. transported fish												
Detected at Bonn.	167	Difference	0	0	-0.67	-0.72	-0.77	-0.87	-1.11	-1.45	-1.9	-1.5
Transported	374	Lower	-0.5	-0.5	-0.7	-0.8	-0.8	-1.0	-1.2	-1.6	-2.3	-1.9
		Upper	-0.4	-0.4	-0.5	-0.7	-0.7	-0.8	-1.0	-1.2	-1.7	-1.3
Wild yearling chinook salmon												
8) Inriver migrants detected at Bonneville Dam vs. transported fish												
Detected at Bonn.	39	Difference	0	0	-0.45	-0.66	-0.69	-0.72	-0.77	-0.85	-1	-0.7
Transported	88	Lower	-0.5	-0.5	-0.7	-0.8	-0.8	-0.8	-0.9	-1.0	-1.5	-1.2
		Upper	-0.2	-0.2	-0.2	-0.5	-0.6	-0.6	-0.7	-0.7	-0.7	-0.3
Inriver migrants detected at Bonneville Dam												
9) Hatchery steelhead vs. wild steelhead												
Hatchery	219	Travel time	1.4	1.5	1.5	1.54	1.58	1.65	1.74	1.82	2.09	0.7
Wild	34	Travel time	1.4	1.4	1.47	1.51	1.62	1.7	1.77	1.79	1.93	0.53
		Difference	0	0	0.03	0.03	0	-0.1	0	0.03	0.16	0.17
		Lower	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.1	-0.1	-0.5	-0.5
		Upper	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.4

Appendix Table 8. Continued.

Species/ Rearing type/ Migration history	n	Bootstrap analysis of the Comparison	Travel time distribution by percentiles 10	20	30	40	50	60	70	80	90	mid 80
Transported fish												
10) Hatchery steelhead vs. wild steelhead												
Hatchery	635	Travel time	1.5	1.6	1.58	1.63	1.68	1.81	1.94	2.44	2.9	1.38
Wild	97	Travel time	1.5	1.6	1.61	1.63	1.68	1.76	1.82	1.9	2.43	0.9
		Difference	0	0	0	0	0.01	0.05	0.12	0.54	0.6	0.61
		Lower	0.0	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.4	0.2	0.2
		Upper	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.7	1.4	1.4
Hatchery steelhead												
11) Inriver migrants detected at Bonneville Dam vs. Transported fish												
Detected at Bonn	219	Difference	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.6	-0.8	-0.7
Transported	635	Lower	-0.2	-0.1	-0.1	-0.1	-0.1	-0.2	-0.3	-0.7	-1.5	-1.3
		Upper	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.5	-0.5	-0.4
Wild steelhead												
12) Inriver migrants detected at Bonneville Dam vs. transported fish												
Detected at Bonn.	34	Difference	0	0	-0.12	-0.12	-0.1	0	-0.1	-0.1	-0.4	-0.3
Transported	97	Lower	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.8	-0.6
		Upper	-0.1	-0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.2	0.4
Inriver migrants detected at Bonneville Dam												
13) Hatchery yearling chinook vs. Hatchery steelhead												
Yearling chinook	167	Difference	0.1	0.1	0.12	0.12	0.13	0.09	0.03	0	-0.2	-0.3
Steelhead	219	Lower	0.0	0.1	0.1	0.1	0.1	0.0	0.0	-0.1	-0.5	-0.6
		Upper	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.0	-0.1
Inriver migrants detected at Bonneville Dam												
14) Wild yearling chinook vs. wild steelhead												
Yearling chinook	39	Difference	0.1	0.2	0.18	0.2	0.145	0.09	0.06	0.08	0	-0.1
Steelhead	34	Lower	-0.1	0.1	0.1	0.0	0.0	0.0	0.0	-0.1	-0.6	-0.7
		Upper	0.2	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.3	0.2

Appendix Table 8. Continued.

Species/ Rearing type/ Migration history	n	Bootstrap analysis of the Comparison	Travel time distribution by percentiles 10	20	30	40	50	60	70	80	90	mid 80
Transported fish												
15) Hatchery yearling chinook vs. hatchery steelhead												
Yearling chinook	374	Difference	0.4	0.5	0.71	0.75	0.79	0.81	0.93	0.82	0.91	0.53
Steelhead	635	Lower	0.4	0.4	0.6	0.7	0.7	0.7	0.8	0.6	0.2	-0.2
		Upper	0.4	0.6	0.8	0.8	0.9	1.0	1.1	1.0	1.4	1.0
Transported fish												
16) Wild yearling chinook vs. wild steelhead												
Yearling chinook	88	Difference	0.3	0.3	0.45	0.75	0.77	0.76	0.78	0.82	0.57	0.29
Steelhead	97	Lower	0.2	0.3	0.3	0.4	0.7	0.7	0.7	0.7	0.2	-0.1
		Upper	0.4	0.5	0.8	0.8	0.9	0.9	0.9	1.0	1.4	1.1
Hatchery yearling chinook												
17) Inriver migrants vs. transported fish												
Inriver migrants	791	Difference	10	12	12.4	13.08	13.62	14.38	14.96	15.65	17.2	7.05
Transported fish	374	Lower	9.2	11.5	12.2	12.7	13.5	14.0	14.6	15.2	16.2	5.9
		Upper	10.9	12.1	12.8	13.2	13.9	14.5	15.2	16.0	17.9	8.1
Wild yearling chinook												
18) Inriver migrants vs. transported fish												
Inriver migrants	168	Difference	11	13	13.62	14.17	14.77	15.45	16.43	17.88	21.6	10.5
Transported fish	88	Lower	8.5	12.4	12.9	13.6	14.3	14.9	15.5	16.7	19.1	7.7
		Upper	12.6	13.6	14.2	14.8	15.3	16.4	17.4	19.4	23.7	14.1
Hatchery steelhead												
19) Inriver migrants vs. transported fish												
Inriver migrants	784	Difference	9.9	12	12.56	13.52	14.76	15.69	17.12	18.11	21.4	11.4
Transported fish	635	Lower	9.6	11.4	12.2	13.4	14.4	15.3	16.5	17.7	20.3	10.1
		Upper	10.6	11.7	12.9	13.9	15.3	16.3	17.5	19.2	22.3	12.6
Wild steelhead												
20) Inriver migrants vs. transported fish												
Inriver migrants	140	Difference	7.5	9	10.38	11.36	11.74	12.39	13.74	15.18	16.1	8.69
Transported fish	97	Lower	6.6	7.9	9.4	10.4	11.4	11.8	12.6	14.1	15.4	7.5
		Upper	8.6	9.7	11.0	11.7	12.4	13.4	14.5	16.2	18.7	11.5

Appendix Table 9. Estimated survival probabilities between McNary (MCN) and John Day Dam (JDA), John Day and Bonneville Dam (BON), and McNary and Bonneville Dam for selected groups of PIT-tagged salmonids detected and returned to the tailrace of McNary Dam in 1999. Daily groups were pooled weekly; estimates are based on the single-release model. Standard errors in parentheses.

Detection date at McNary Dam	Number released	MCN to JDA	JDA to BON	MCN to BON
Snake River yearling chinook salmon				
20 Apr-26 Apr	1,940	0.777 (0.045)	1.0[b] (0.809)	1.0[b] (0.624)
27 Apr-03 May	8,436	0.753 (0.025)	0.746 (0.100)	0.562 (0.073)
04 May-10 May	19,646	0.905 (0.024)	0.681 (0.068)	0.616 (0.059)
11 May-17 May	24,447	0.846 (0.019)	0.858 (0.080)	0.726 (0.066)
18 May-24 May	14,413	0.907 (0.037)	0.948 (0.142)	0.859 (0.124)
25 May-31 May	6,670	0.988 (0.082)	0.911 (0.199)	0.900 (0.182)
Weighted mean[c]		0.853 (0.030)	0.814 (0.065)	0.704 (0.058)
Snake River steelhead				
20 Apr-26 Apr	331	1.0[b] (0.130)	0.521 (0.193)	0.544 (0.190)
27 Apr-03 May	1,183	1.0[b] (0.077)	0.574 (0.140)	0.582 (0.135)
04 May-10 May	2,876	0.942 (0.042)	0.706 (0.113)	0.666 (0.102)
11 May-17 May	2,023	0.969 (0.060)	0.748 (0.185)	0.725 (0.174)
18 May-24 May	1,794	0.777 (0.044)	0.892 (0.316)	0.693 (0.243)
25 May-31 May	4,246	0.915 (0.041)	0.655 (0.127)	0.600 (0.113)
Weighted mean[c]		0.920 (0.033)	0.682 (0.039)	0.640 (0.024)
Mid-Columbia River yearling chinook salmon				
04 May-10 May	1,282	0.938 (0.087)	0.532 (0.184)	0.499 (0.167)
11 May-17 May	1,810	0.872 (0.066)	1.0[b] (0.381)	0.960 (0.324)
18 May-24 May	1,641	0.772 (0.067)	0.695 (0.240)	0.536 (0.180)
25 May-31 May	1,446	0.759 (0.073)	0.524 (0.146)	0.398 (0.105)
Weighted mean[c]		0.838 (0.041)	0.690 (0.131)	0.570 (0.122)

Appendix Table 9. Continued.

Detection date at McNary Dam	Number released	MCN to JDA		JDA to BON		MCN to BON	
Mid-Columbia River steelhead							
27 Apr-03 May	1,225	1.0[b]	(0.100)	0.511	(0.161)	0.574	(0.173)
04 May-10 May	5,017	1.0[b]	(0.046)	0.612	(0.095)	0.659	(0.098)
11 May-17 May	4,940	1.0[b]	(0.045)	0.913	(0.184)	0.959	(0.189)
18 May-24 May	4,177	1.0[b]	(0.045)	0.895	(0.291)	0.897	(0.289)
25 May-31 May	3,419	0.883	(0.042)	0.652	(0.220)	0.575	(0.192)
Weighted mean[c]		1.014	(0.034)	0.712	(0.076)	0.742	(0.076)

a Hatchery and wild fish, all Snake River Basin sources.

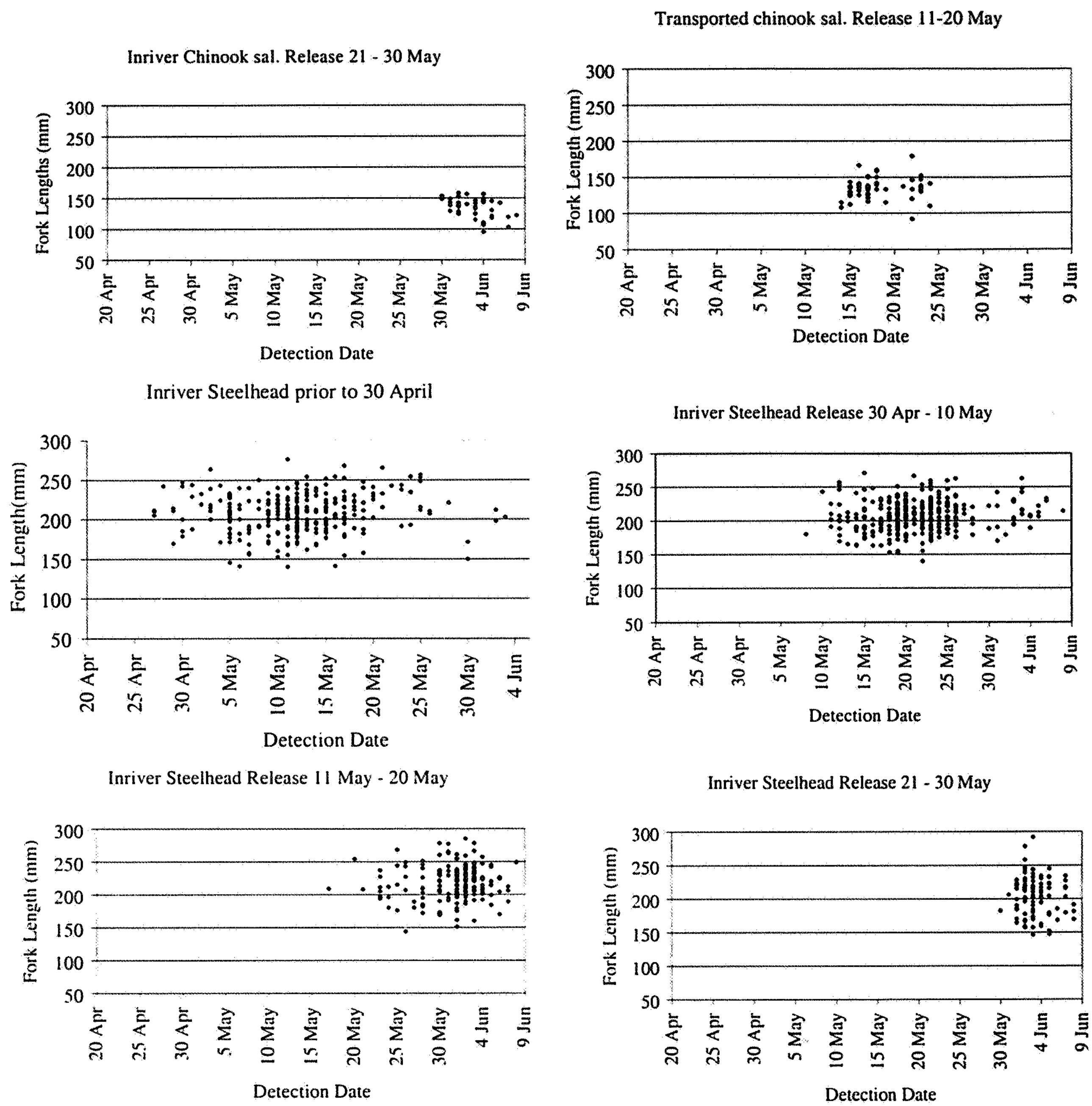
b Model-based estimate greater than 1.0.

c Weighted means of the independent estimates for weekly pooled groups, with weights inversely proportional to respective estimated relative variances.

d Hatchery fish from Winthrop and Leavenworth hatcheries; Yakima River drainage rearing ponds.

e Hatchery fish released by Chelan and Douglas County Public Utility Districts.

Appendix Figure 1. Lengths at time of tagging for transportation study yearling chinook salmon and steelhead released at Lower Granite Dam for inriver migration or transported and released downstream from Bonneville Dam and subsequently detected in the estuary at Jones Beach, 1999. Data were grouped by week of tagging, correlation coefficients R^2 ranged from 0.0001 to 0.1090.



Appendix Figure 1. Continued.